Draft Technical Guidelines for Voluntary Reporting of Greenhouse Gas Program
Chapter 1, Emission Inventories
Part I: Appendix

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Appendix Section 1: Tables of Ecosystem Carbon for Common Forestry Activities and Forest Conditions

1.1 Introduction

A basic approach to estimating carbon stock inventories is to use look-up tables that represent average forest conditions for a region, forest type, and productivity class. Before using the look-up tables, it is necessary to determine the area of land to be included in the estimate, and characterize that area in a way that is compatible with the estimates in the look-up tables. Then the average values presented in the look-up tables can be multiplied by the area estimate to obtain the carbon stock estimate. Although this approach is simple and inexpensive to use, the uncertainty of results generated using this approach may be high relative to other approaches that utilize data on specific circumstances of the activity or entity. The look-up tables are most appropriately used for afforestation and reforestation activities, with options for calculating the effects of harvesting on carbon pools (methods for harvested wood products are covered in section 4 of this Appendix).

Look-up tables are based on inventories of forests conducted across the U.S. Since these tables represent average conditions over large areas, the actual carbon flows for a specific activity or entity may be different than the estimate developed by using the default carbon factors in the look-up tables. The look-up table approach is not appropriate if it is determined that the conditions for an activity or entity are not represented by the look-up tables.

Estimates in look-up tables are termed “default estimates” to indicate that they should be used when it is impractical to use other methods. Default estimates of forest carbon stocks and stock changes are presented in tables delineated by forest types and regions of the United States. The tables include average carbon stocks for each of six separate ecosystem carbon pools, specifically: live trees, standing dead trees, understory vegetation, down dead wood, the forest floor, and soil organic carbon. Estimated values are largely based on USDA Forest Service, Forest Inventory and Analysis (FIA) inventory data and forest simulation models used in the development of national-scale forest carbon budgets. These tables are revisions of default tables that accompanied the previous version of Greenhouse Gas Accounting Rules and Guidelines for Forestry. Their development and format are based on the tables developed by Birdsey (1996).

Tables are organized to provide default carbon stock estimates for common forest type classifications in each of ten regions (Figure 1). Carbon mass density, as metric tons carbon per hectare, is further related to stand age or growing-stock volume (the volume of merchantable wood as defined by FIA, hereafter referred to as “volume”). That is, once the appropriate management scenario, region, forest type, and age or volume are specified, the tabular format provides carbon in metric tons per hectare.

1.2 Appropriate use of tables and accuracy assessment

Estimated carbon stocks are average values, which are representative of large areas of similarly defined ecosystems. These tables are intended for use where more specific information is not available. Some carbon sequestration projects may require different information than is provided by these tables. Therefore, we also include the underlying assumptions and appropriate citations so that the tables can be modified to adjust to the data availability and information requirements of individual activities.

Two sets of tables provide information corresponding to some possible scenarios of carbon sequestration activities. The first set of tables characterizes carbon stocks during regrowth, or reforestation, of a stand following a clearcut harvest. The second set summarizes accumulation of carbon stocks for a stand established on land not previously classified as forestland, called afforestation. The rationale for the separate set of afforestation tables is to account for lower carbon densities of standing dead trees, down dead wood, forest floor, and soil carbon in the initial years after forest establishment. However, as the stands mature the level of carbon stocks in these pools approach the regional averages represented in the tables for forest regrowth following harvest.

The definitions of key table categories, which must be matched to each application, are defined in Smith et al. (2001) and are also available from USDA Forest Service (2002a). Some of the forest type groups in the South and Pacific Northwest used to define tables within regions are subdivided into "natural" and "planted", as well as "productivity class". Also in the South and Pacific Northwest, management intensity may be subdivided into "lower" and "higher". For Douglas-fir in the Pacific Northwest, lower management intensity involves replanting, while higher management intensity involves replanting genetically improved stock, fertilization, and precommercial thinning. For planted pines in the South, lower management intensity involves replanting with genetically improved stock, while higher management intensity also includes fertilization and competition control.

The tables are designed as default estimates when other information is not available, and they can complement incomplete information. Thus, separate estimates are provided for each carbon pool to facilitate merging with locally-specific data when available. For example, if soils data are available, the soil column can be replaced with the locally-specific data. Similarly, other growth and yield relationships can be employed. As discussed in the methods section below, an age-volume relationship—or yield curve—is provided, based on information from the timber projection model ATLAS (Mills and Kincaid 1992, with updates for Haynes 2003). ATLAS uses growth and yield data to describe a set of volume tables for projecting large-scale forest inventories representing U.S. forests under different policy scenarios. Users with growth and yield information other than that provided with the default tables can still use the tables by matching forest type and interpolating carbon values for the appropriate age or volume. Remember that forest floor is a function of stand age, and the remaining carbon pools are functions of volume.

Tables vary in length according to the individual growth and yield data associated with the forest types. Stand establishment is at year zero. Note that the age column represents the age of the stand.

The accuracy of estimates from look-up tables will depend on how well the estimates in the tables represent the specific conditions of the land area or stratum for which estimates are required. In general, application of a regional estimate from a look-up table to a specific tract of land will get a rating of "C" to reflect the level of uncertainty inherent in this approach. However, a close match between the characteristics of the specific land area and the land characteristics defined by a look-up table could result in a higher rating. The following tabulation illustrates how look-up tables may be rated under the 1605(b) reporting system. This is intended as a guide to rating – individual circumstances must be carefully considered before conducting such an accuracy assessment.

Rating	*Points*	*Characterization*	*Application of look-up tables*
A	4	Most accurate (within 10 % of true value)	Estimates in look-up tables validated with independent data for the specific site and management conditions.
B	3	Adequate accuracy (within 20 % of true value)	Estimates in look-up tables modified or adjusted to match the specific site and management conditions. For example, estimates of carbon in live and standing dead trees are re-calculated using local biomass equations for a narrowly defined productivity class.
C	2	Marginal accuracy (within 30 % of true value)	Typical application of regional look-up tables that generally match the site and management conditions. Sites are defined by region, forest type, and productivity class. Management includes regeneration after harvest, afforestation, and in some cases, "low" or "high" intensity.
D	1	Inadequate accuracy	Use of look-up tables for sites or management conditions that are not represented by the tables. For example, using the Northeast, White-red-jack pine table for an intensively managed, thinned red pine plantation.

1.3 Forest ecosystem carbon estimates

Carbon estimates provided in the default tables are from the individual carbon-pool estimators in the national-level forest carbon accounting model FORCARB2 (Heath and others 2003). FORCARB2 is essentially a national-scale empirical simulation and carbon accounting model that produces inventory-based estimates of carbon stocks both in forest ecosystems and in harvested wood. Additional details about FORCARB2 and estimates of forest carbon stocks can be found in Smith and Heath (2002), Heath and others (2003), Smith and others (2003), and USDA (2004).

Forest structure provides a convenient modeling framework for assigning carbon to distinct pools. Carbon stocks in forest ecosystems are estimated as six distinct pools, which are as follows:

> **Live trees**, live trees with diameter at breast height (dbh) of at least 2.5 cm (1 inch), includes carbon mass of coarse roots (greater than 0.2-0.5 cm, published distinctions between fine and coarse roots are not always clear), stems, branches, and foliage.
> **Standing dead trees**, standing dead trees with dbh of at least 2.5 cm, includes carbon mass of coarse roots, stems, and branches.
> **Understory vegetation**, including the roots, stems, branches, and foliage of seedlings (trees less than 2.5 cm dbh), shrubs, and bushes.
> **Down dead wood**, including logging residue and other coarse dead wood on the ground and larger than 7.5 cm diameter, and stumps and coarse roots of stumps.
> **Forest floor**, including fine woody debris up to 7.5 cm diameter, tree litter, humus, and fine roots in the organic forest floor layer above mineral soil.
> **Soil organic carbon**, includes fine roots and all other organic carbon not included in above pools, to a depth of 1 meter.

Estimates of carbon in live and standing dead trees are based on the methods of Jenkins and others (2003) and Smith and others (2003). New sets of individual tree equations were developed from the database described by Jenkins and others (2004) with the goal of greater regional specificity in biomass estimates. A new set of stand level volume-to-biomass equations were calibrated to the USDA Forest Service, Forest Inventory and Analysis database (FIADB) as of January 8, 2004. These are the bases for the live and standing dead values provided here. Detail will be forthcoming in subsequent FORCARB2 publications.

Soil organic carbon is based on estimates according to forest type as described in Johnson and Kern (2003) and Heath and others (2003). Actual values assigned to forest types employed by the tables are based on the distribution of types in the USDA Forest Service Renewable Resources Planning Act (RPA) 2002 Forest Resource Assessment database. See USDA Forest Service (2002a) for the 2002 RPA database, and see Smith and others (2001) for additional information about forest resource statistics.

The afforestation tables are based on the FORCARB2 model and the reforestation tables. Since the residual carbon of standing dead trees, down dead wood, and existing forest floor material left after harvest does not exist for afforested stands, these are assumed to be zero at the stand age zero. Only carbon accumulated within the afforested stand is included in the tables. Accumulation of soil organic carbon in previously nonforested land follows the accumulation function described in West and others (2004).

Examples: Applying stand-level tables to estimate tons of carbon per hectare of forestland.

Stand-level carbon density = *Live tree* + *Standing dead tree* + *Understory*
+ *Down dead wood* + *Forest floor* + *Soil*

A 20-year-old stand of highly productive naturally regenerated pine in the Southeast has 42.4 tons of carbon in live trees and a total of 165 tons of carbon per hectare.

Stand-level carbon density = 42.4 + 0.9 + 3.2 + 6.0 + 8.7 + 104
165 (metric tons carbon per hectare)

A newly established maple-beech-birch stand in the Northeast will accumulate an average of 2.5 tons carbon per hectare per year on nonsoil carbon over the first 55 years.

Average accumulation per year = 138 (at 55 years) / 55 years
2.5 (metric tons carbon per hectare)

1.4 Carbon in harvested wood

Tables of ecosystem carbon do not account for carbon in harvested wood. A separate appendix provides technical guidelines for estimating and accounting for carbon in harvested wood. If carbon remaining in wood products is not part of the accounting system, the calculation of carbon stock change for the forest area that is harvested will indicate that all of the removed carbon is immediately released to the atmosphere. Failing to account for carbon in wood products significantly overestimates emissions to the atmosphere.

The guidelines in the harvested wood appendix can be used in conjunction with these ecosystem carbon guidelines. In the harvested wood appendix, look-up tables are provided for different harvested carbon pools. The reporter can use the ecosystem tables in this appendix to track carbon up to the time of harvest. Two tables are required to track carbon after harvest. One table accounts for dynamics of ecosystem carbon after harvest (this appendix), and the other table accounts for the changes in carbon removed from the forest ecosystem (the harvested wood appendix). The look-up tables provided here for reforestation after harvest assume that the age of the forest stand is reset to zero; that is, information is only provided for clearcut harvests. If the forest type is shifted to a new forest type after harvest, the appropriate default table should be used.

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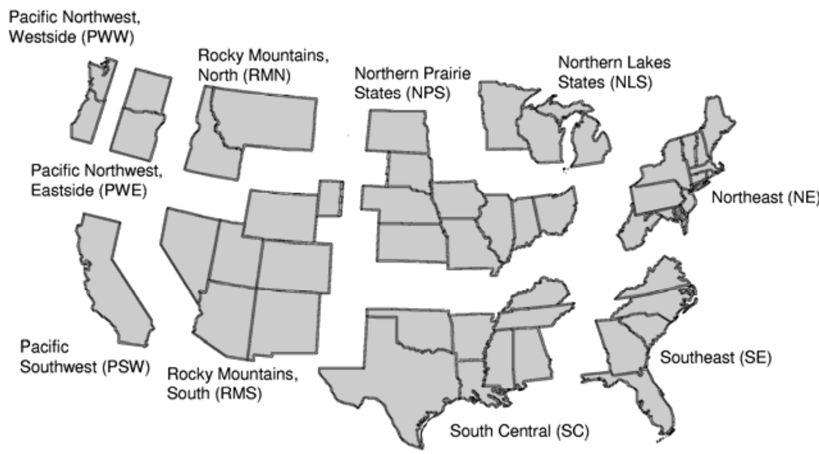

Figure 1. Regions associated with the forest types defined for the default tables: Pacific Northwest, Westside (PWW); Pacific Northwest, Eastside (PWE); Pacific Southwest (PSW); Rocky Mountain, North (RMN); Rocky Mountain, South (RMS); Northern Plains States (NPS); Northern Lake States (NLS); Northeast (NE); South Central (SC); and Southeast (SE).

Chapter 1, GHG Inventories: Part I
Appendix Section 1: Tables R1-R70
Reforestation, or regrowth after harvest, tables.

List of tables

R41. Pacific Northwest, Westside, Western Hemlock, medium productivity sites (growth rate between 120 and 224 cubic feet wood per acre per year)
R42. Rocky Mountain, North, Douglas-fir
R43. Rocky Mountain, North, Fir & Spruce
R44. Rocky Mountain, North, Lodgepole Pine
R45. Rocky Mountain, North, Ponderosa Pine
R46. Rocky Mountain, South, Douglas-fir
R47. Rocky Mountain, South, Fir & Spruce
R48. Rocky Mountain, South, High Elevation
R49. Rocky Mountain, South, Lodgepole Pine
R50. Rocky Mountain, South, Ponderosa Pine
R51. South Central, Lowland Hardwood
R52. South Central, Natural Pine, high productivity sites (growth rate greater than 120 cubic feet wood per acre per year)
R53. South Central, Natural Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year)
R54. South Central, Oak-Pine, high productivity sites (growth rate greater than 120 cubic feet wood per acre per year)
R55. South Central, Oak-Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year)
R56. South Central, Planted Pine, high productivity sites (growth rate greater than 120 cubic feet wood per acre per year), lower intensity management
R57. South Central, Planted Pine, high productivity sites (growth rate greater than 120 cubic feet wood per acre per year), higher intensity management
R58. South Central, Planted Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year), lower intensity management
R59. South Central, Planted Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year), higher intensity management
R60. South Central, Upland Hardwoods
R61. Southeast, Lowland Hardwood
R62. Southeast, Natural Pine, high productivity sites (growth rate greater than 85 cubic feet wood per acre per year)
R63. Southeast, Natural Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year)
R64. Southeast, Oak-Pine, high productivity sites (growth rate greater than 85 cubic feet wood per acre per year)
R65. Southeast, Oak-Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year)
R66. Southeast, Planted Pine, high productivity sites (growth rate greater than 85 cubic feet wood per acre per year), lower intensity management
R67. Southeast, Planted Pine, high productivity sites (growth rate greater than 85 cubic feet wood per acre per year), higher intensity management
R68. Southeast, Planted Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year), lower intensity management
R69. Southeast, Planted Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year), higher intensity management
R70. Southeast, Upland Hardwoods

R1. Northeast, Aspen & Birch

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	10.5	10.2	237	22
5	0	16.0	0.5	2.2	7.4	7.5	237	33
15	13	22.5	1.5	2.1	4.4	6.0	237	37
25	34	32.9	2.2	2.1	3.7	6.5	237	47
35	58	45.0	2.9	2.1	4.0	7.5	237	61
45	85	57.7	3.5	2.1	4.7	8.5	237	76
55	112	70.8	4.2	2.1	5.6	9.3	237	92
65	142	84.4	4.8	2.0	6.6	10.1	237	108
75	173	98.3	5.4	2.0	7.7	10.7	237	124
85	205	112.7	5.9	2.0	8.8	11.3	237	141
95	239	127.4	6.3	2.0	9.9	11.8	237	157
105	274	142.4	6.7	2.0	11.1	12.2	237	174
115	311	157.6	7.1	2.0	12.3	12.5	237	191
125	350	173.1	7.3	2.0	13.5	12.9	237	209
135	390	188.7	7.5	2.0	14.7	13.2	237	226
145	432	204.5	7.7	2.0	15.9	13.4	237	243
155	475	220.3	7.8	2.0	17.1	13.7	237	261
165	520	236.3	7.8	2.0	18.4	13.9	237	278
175	566	252.2	7.8	2.0	19.6	14.1	237	296

R2. Northeast, Elm, Ash, Red Maple

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.8	10.9	27.7	134	39
5	0	22.1	0.8	1.9	7.8	20.3	134	53
15	31	38.2	2.4	1.8	5.4	16.3	134	64
25	62	54.4	3.5	1.8	5.0	17.6	134	82
35	97	72.7	4.6	1.7	5.7	20.3	134	105
45	133	90.7	5.6	1.7	6.7	23.0	134	128
55	166	107.2	6.4	1.7	7.7	25.3	134	148
65	196	122.4	7.0	1.7	8.7	27.4	134	167
75	225	136.1	7.2	1.7	9.7	29.2	134	184
85	251	148.6	7.2	1.6	10.5	30.7	134	199
95	274	159.9	7.0	1.6	11.3	32.0	134	212
105	296	169.9	6.7	1.6	12.0	33.1	134	223
115	314	178.7	6.2	1.6	12.7	34.2	134	233
125	331	186.4	5.7	1.6	13.2	35.1	134	242
135	345	192.9	5.3	1.6	13.7	35.9	134	249
145	357	198.3	4.9	1.6	14.0	36.6	134	255
155	367	202.6	4.5	1.6	14.3	37.3	134	260
165	374	205.9	4.3	1.6	14.6	37.9	134	264
175	378	208.0	4.1	1.6	14.7	38.4	134	267

R3. Northeast, Maple, Beech, Birch

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.8	9.9	27.7	140	38
5	0	22.1	0.8	1.9	7.1	20.3	140	52
15	28	36.9	2.4	1.8	5.0	16.3	140	62
25	58	52.6	3.4	1.8	4.8	17.6	140	80
35	90	68.9	4.4	1.7	5.3	20.3	140	101
45	119	83.9	5.3	1.7	6.1	23.0	140	120
55	147	97.7	6.0	1.7	7.0	25.3	140	138
65	172	110.4	6.6	1.7	7.9	27.4	140	154
75	196	122.0	7.0	1.7	8.7	29.2	140	168
85	217	132.5	7.2	1.7	9.4	30.7	140	181
95	237	141.9	7.3	1.7	10.1	32.0	140	193
105	254	150.3	7.2	1.6	10.6	33.1	140	203
115	270	157.7	7.1	1.6	11.2	34.2	140	212
125	283	164.1	6.9	1.6	11.6	35.1	140	219
135	295	169.4	6.7	1.6	12.0	35.9	140	226
145	304	173.9	6.5	1.6	12.3	36.6	140	231
155	312	177.4	6.3	1.6	12.6	37.3	140	235
165	317	180.0	6.1	1.6	12.7	37.9	140	238
175	321	181.6	6.0	1.6	12.9	38.4	140	241

R4. Northeast, Oak & Hickory

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.9	12.9	8.2	85	22
5	0	22.2	1.0	2.0	9.1	5.7	85	40
15	55	52.0	3.0	1.9	6.9	4.1	85	68
25	96	74.1	4.0	1.8	6.5	4.5	85	91
35	135	94.8	4.7	1.8	7.1	5.3	85	114
45	173	114.4	5.1	1.8	8.1	6.3	85	136
55	210	132.7	5.1	1.8	9.2	7.3	85	156
65	244	149.9	5.0	1.8	10.3	8.1	85	175
75	277	166.0	4.7	1.8	11.4	8.9	85	193
85	309	181.1	4.2	1.8	12.4	9.7	85	209
95	339	195.3	3.8	1.8	13.4	10.3	85	224
105	367	208.4	3.3	1.8	14.3	10.9	85	239
115	394	220.6	2.9	1.7	15.1	11.5	85	252
125	419	232.0	2.4	1.7	15.9	12.0	85	264
135	442	242.4	2.1	1.7	16.6	12.5	85	275
145	464	252.1	1.8	1.7	17.2	12.9	85	286
155	484	260.9	1.5	1.7	17.8	13.3	85	295
165	502	268.9	1.3	1.7	18.4	13.7	85	304
175	519	276.2	1.1	1.7	18.9	14.1	85	312

R5. Northeast, Oak & Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.1	8.2	29.7	82	39
5	0	18.6	0.8	3.6	6.5	20.2	82	50
15	37	37.3	2.3	3.0	5.3	15.3	82	63
25	71	54.6	3.3	2.8	5.1	17.1	82	83
35	103	70.4	4.2	2.6	5.3	20.3	82	103
45	133	84.9	4.8	2.5	5.8	23.6	82	122
55	161	98.1	5.3	2.4	6.3	26.6	82	139
65	187	110.2	5.6	2.4	6.9	29.3	82	154
75	210	121.0	5.7	2.3	7.5	31.6	82	168
85	232	130.7	5.7	2.3	8.1	33.6	82	180
95	251	139.4	5.5	2.2	8.6	35.4	82	191
105	268	147.0	5.4	2.2	9.0	37.0	82	201
115	283	153.5	5.2	2.2	9.4	38.4	82	209
125	295	159.1	4.9	2.2	9.7	39.7	82	216
135	306	163.7	4.8	2.1	10.0	40.9	82	222
145	314	167.3	4.6	2.1	10.2	42.0	82	226
155	321	170.0	4.5	2.1	10.4	43.0	82	230
165	325	171.7	4.4	2.1	10.5	43.9	82	233
175	327	172.5	4.3	2.1	10.6	44.7	82	234

R6. Northeast, Spruce & Balsam Fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.6	9.6	33.7	193	44
5	0	19.3	1.0	1.6	7.7	23.6	193	53
15	11	24.3	3.1	1.5	5.6	18.6	193	53
25	29	31.9	4.0	1.5	4.9	20.7	193	63
35	52	41.5	5.1	1.5	4.9	24.2	193	77
45	77	52.0	6.2	1.4	5.4	27.7	193	93
55	103	62.6	7.1	1.4	6.1	30.7	193	108
65	126	72.2	7.8	1.4	6.9	33.3	193	122
75	149	81.3	8.2	1.3	7.6	35.5	193	134
85	171	89.9	8.6	1.3	8.4	37.4	193	146
95	192	97.9	8.7	1.3	9.1	39.1	193	156
105	211	105.4	8.8	1.3	9.7	40.6	193	166
115	230	112.3	8.8	1.3	10.4	41.9	193	175
125	247	118.9	8.7	1.3	11.0	43.0	193	183
135	264	125.0	8.6	1.3	11.5	44.0	193	190
145	279	130.7	8.4	1.3	12.1	45.0	193	197
155	294	136.0	8.2	1.3	12.5	45.8	193	204
165	310	142.0	7.9	1.3	13.1	46.6	193	211
175	326	147.7	7.6	1.2	13.6	47.3	193	217

R7. Northeast, White, Red & Jack Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.8	5.9	13.8	196	20
5	0	19.9	0.5	1.9	4.7	10.7	196	38
15	30	33.1	1.5	1.8	3.9	9.4	196	50
25	54	43.6	2.0	1.8	3.6	10.1	196	61
35	78	53.6	2.5	1.7	3.6	11.2	196	73
45	101	63.1	2.9	1.7	3.9	12.2	196	84
55	123	72.2	3.3	1.7	4.2	13.1	196	94
65	142	80.2	3.7	1.6	4.5	13.7	196	104
75	161	87.7	4.0	1.6	4.9	14.2	196	112
85	178	94.7	4.3	1.6	5.3	14.7	196	121
95	195	101.1	4.5	1.6	5.6	15.0	196	128
105	210	107.1	4.8	1.6	5.9	15.4	196	135
115	224	112.5	4.9	1.6	6.2	15.6	196	141
125	237	117.5	5.1	1.6	6.5	15.9	196	146
135	249	122.1	5.2	1.6	6.7	16.1	196	152
145	260	126.2	5.3	1.6	7.0	16.2	196	156
155	270	130.0	5.3	1.5	7.2	16.4	196	160
165	282	134.3	5.4	1.5	7.4	16.5	196	165
175	293	138.5	5.4	1.5	7.6	16.7	196	170

R8. Northern Lake States, Aspen & Birch

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	9.8	10.2	237	21
5	0	13.9	1.6	2.1	6.9	7.5	237	32
15	76	51.2	5.0	2.0	6.7	6.0	237	71
25	150	85.6	7.9	2.0	8.0	6.5	237	110
35	208	110.8	8.7	2.0	9.4	7.5	237	138
45	231	120.5	8.4	2.0	9.9	8.5	237	149
55	240	124.3	8.2	2.0	10.1	9.3	237	154
65	243	125.8	8.1	2.0	10.2	10.1	237	156
75	245	126.4	8.1	2.0	10.2	10.7	237	157
85	246	126.7	8.1	2.0	10.2	11.3	237	158

R9. Northern Lake States, Jack Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	5.8	13.8	196	21
5	0	12.8	0.5	2.0	4.6	10.7	196	31
15	37	27.3	1.6	2.0	4.1	9.4	196	44
25	82	44.3	2.5	2.0	4.4	10.1	196	63
35	120	58.5	3.2	2.0	4.9	11.2	196	80
45	146	68.2	3.6	2.0	5.3	12.2	196	91
55	163	74.2	3.8	2.0	5.6	13.1	196	99
65	172	77.7	3.9	2.0	5.7	13.7	196	103
75	178	79.7	3.9	2.0	5.8	14.2	196	106
85	181	80.8	4.0	2.0	5.9	14.7	196	107
95	183	81.5	4.0	2.0	5.9	15.0	196	108
105	184	81.8	4.0	2.0	5.9	15.4	196	109

R10. Northern Lake States, Lowland Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	10.0	27.7	118	39
5	0	14.7	1.7	1.9	6.9	20.3	118	46
15	63	49.4	5.0	1.9	5.7	16.3	118	78
25	119	80.1	7.0	1.9	6.1	17.6	118	113
35	162	103.8	7.9	1.9	6.9	20.3	118	141
45	199	123.9	8.3	1.9	7.8	23.0	118	165
55	230	140.2	8.4	1.9	8.7	25.3	118	185
65	254	153.4	8.3	1.9	9.5	27.4	118	201
75	271	162.4	8.2	1.9	10.0	29.2	118	212
85	282	168.5	8.2	1.9	10.4	30.7	118	220
95	286	170.7	8.1	1.9	10.5	32.0	118	223
105	350	204.7	7.4	1.9	12.6	33.1	118	260

R11. Northern Lake States, Maple & Beech

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.6	10.0	27.7	140	38
5	0	15.0	0.4	1.7	7.0	20.3	140	44
15	1	15.8	1.2	1.7	3.8	16.3	140	39
25	10	21.4	1.6	1.6	2.7	17.6	140	45
35	34	36.3	2.7	1.5	3.2	20.3	140	64
45	73	59.3	4.2	1.5	4.7	23.0	140	93
55	118	85.2	5.5	1.4	6.6	25.3	140	124
65	162	109.4	6.3	1.4	8.3	27.4	140	153
75	200	129.7	6.6	1.3	9.8	29.2	140	177
85	230	145.4	6.5	1.3	11.0	30.7	140	195
95	253	157.2	6.4	1.3	11.9	32.0	140	209
105	271	165.7	6.2	1.3	12.6	33.1	140	219
115	283	171.8	6.1	1.3	13.0	34.2	140	226
125	292	176.1	6.0	1.3	13.3	35.1	140	232
135	298	179.0	5.9	1.3	13.6	35.9	140	236
145	302	181.1	5.8	1.3	13.7	36.6	140	239
155	306	182.6	5.8	1.3	13.8	37.3	140	241
165	308	183.6	5.8	1.3	13.9	37.9	140	242
175	309	184.2	5.7	1.3	14.0	38.4	140	244

R12. Northern Lake States, Oak & Hickory

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.8	15.3	8.2	85	24
5	0	21.8	1.5	2.0	10.7	5.7	85	42
15	66	64.1	4.5	1.8	8.9	4.1	85	83
25	106	88.8	5.6	1.7	8.6	4.5	85	109
35	145	112.2	6.0	1.7	9.4	5.3	85	135
45	182	133.7	5.9	1.7	10.7	6.3	85	158
55	216	153.2	5.5	1.7	12.0	7.3	85	180
65	248	170.5	4.9	1.6	13.2	8.1	85	198
75	276	186.0	4.2	1.6	14.4	8.9	85	215
85	302	199.6	3.6	1.6	15.4	9.7	85	230
95	326	211.7	3.1	1.6	16.4	10.3	85	243
105	347	222.3	2.6	1.6	17.2	10.9	85	255
115	365	231.6	2.2	1.6	17.9	11.5	85	265
125	382	239.8	1.9	1.6	18.5	12.0	85	274
135	396	247.1	1.7	1.6	19.1	12.5	85	282
145	409	253.4	1.5	1.6	19.6	12.9	85	289
155	421	258.9	1.3	1.6	20.0	13.3	85	295
165	431	263.8	1.2	1.6	20.4	13.7	85	301
175	440	268.1	1.0	1.6	20.7	14.1	85	306

R13. Northern Lake States, Red Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	17.4	13.8	196	32
5	0	12.8	1.0	2.0	13.4	10.7	196	40
15	115	56.6	3.1	2.0	11.2	9.4	196	82
25	232	98.9	4.2	2.0	11.2	10.1	196	126
35	356	141.5	3.2	2.0	12.5	11.2	196	170
45	480	182.0	3.0	2.0	14.4	12.2	196	212
55	600	218.7	3.0	1.9	16.5	13.1	196	251
65	708	250.5	3.0	1.9	18.5	13.7	196	285
75	802	276.8	3.0	1.9	20.2	14.2	196	313
85	878	297.1	3.0	1.9	21.5	14.7	196	335
95	932	311.4	3.0	1.9	22.5	15.0	196	351

R14. Northern Lake States, Spruce & Balsam Fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.6	8.9	33.7	193	43
5	0	14.0	0.9	2.3	7.0	23.6	193	48
15	47	36.4	2.6	1.7	6.5	18.6	193	66
25	83	53.1	3.8	1.5	6.5	20.7	193	86
35	114	66.6	4.8	1.4	6.8	24.2	193	104
45	141	78.7	5.7	1.3	7.4	27.7	193	121
55	157	85.5	6.2	1.3	7.7	30.7	193	131
65	173	92.2	6.7	1.2	8.2	33.3	193	142
75	186	97.8	7.1	1.2	8.6	35.5	193	150
85	206	105.9	7.6	1.2	9.2	37.4	193	161
95	212	108.4	7.8	1.2	9.4	39.1	193	166
105	220	111.5	8.0	1.2	9.7	40.6	193	171
115	225	113.6	8.2	1.2	9.8	41.9	193	175
125	219	111.4	8.0	1.2	9.6	43.0	193	173
135	223	113.0	8.1	1.2	9.8	44.0	193	176
145	241	120.3	8.6	1.1	10.4	45.0	193	185
155	243	121.0	8.7	1.1	10.5	45.8	193	187

R15. Northern Lake States, Swamp Conifer

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.6	6.6	33.7	193	41
5	0	14.0	0.3	2.3	5.3	23.6	193	45
15	0	14.2	1.0	2.3	3.5	18.6	193	40
25	3	15.4	1.1	2.2	2.7	20.7	193	42
35	21	24.3	1.8	1.9	2.9	24.2	193	55
45	44	35.1	2.5	1.7	3.5	27.7	193	71
55	72	47.8	3.5	1.5	4.4	30.7	193	88
65	98	59.7	4.3	1.4	5.3	33.3	193	104
75	122	70.2	5.1	1.4	6.2	35.5	193	118
85	142	78.9	5.7	1.3	6.9	37.4	193	130
95	149	82.0	5.9	1.3	7.1	39.1	193	135
105	156	85.0	6.2	1.3	7.4	40.6	193	140
115	162	87.8	6.4	1.3	7.6	41.9	193	145
125	167	89.8	6.5	1.3	7.8	43.0	193	148
135	171	91.2	6.6	1.2	7.9	44.0	193	151
145	173	92.4	6.7	1.2	8.0	45.0	193	153
155	175	93.1	6.7	1.2	8.1	45.8	193	155

R16. Northern Lake States, White Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	15.9	13.8	196	31
5	0	12.8	0.8	2.0	12.2	10.7	196	39
15	70	39.8	2.3	2.0	9.3	9.4	196	63
25	168	76.0	3.8	2.0	9.2	10.1	196	101
35	283	116.8	4.0	2.0	10.5	11.2	196	145
45	398	155.5	2.5	2.0	12.4	12.2	196	185
55	503	189.0	2.3	1.9	14.3	13.1	196	219
65	592	216.5	2.3	1.9	16.0	13.7	196	249
75	666	238.3	2.3	1.9	17.4	14.2	196	272
85	725	255.3	2.3	1.9	18.5	14.7	196	290
95	772	268.3	2.3	1.9	19.4	15.0	196	305
105	808	278.2	2.3	1.9	20.1	15.4	196	316
115	835	285.8	2.3	1.9	20.6	15.6	196	324
125	856	291.5	2.3	1.9	21.0	15.9	196	330
135	873	295.8	2.3	1.9	21.3	16.1	196	335
145	885	299.0	2.3	1.9	21.5	16.2	196	339
155	894	301.4	2.3	1.9	21.7	16.4	196	341
165	901	303.2	2.3	1.9	21.8	16.5	196	344
175	906	304.6	2.3	1.9	21.9	16.7	196	345

R17. Northern Prairie States, Lowland Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.9	7.6	27.7	126	36
5	0	33.3	1.4	2.1	5.8	20.3	126	63
15	33	49.1	4.3	2.0	4.9	16.3	126	77
25	46	55.8	4.7	1.9	4.5	17.6	126	85
35	59	61.7	5.0	1.9	4.6	20.3	126	93
45	70	67.0	5.3	1.9	4.8	23.0	126	102
55	80	71.8	5.5	1.8	5.0	25.3	126	110
65	89	76.0	5.7	1.8	5.3	27.4	126	116
75	96	79.9	5.9	1.8	5.5	29.2	126	122
85	104	83.3	6.0	1.8	5.8	30.7	126	127
95	110	86.3	6.1	1.8	6.0	32.0	126	132
105	116	89.0	6.2	1.8	6.2	33.1	126	136
115	121	91.5	6.3	1.8	6.3	34.2	126	140
125	125	93.7	6.3	1.8	6.5	35.1	126	143
135	130	95.6	6.4	1.8	6.6	35.9	126	146
145	133	97.4	6.5	1.7	6.7	36.6	126	149
155	136	98.9	6.5	1.7	6.9	37.3	126	151
165	137	99.1	6.5	1.7	6.9	37.9	126	152

R18. Northern Prairie States, Maple & Beech

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.6	6.8	27.7	140	35
5	0	24.2	0.9	1.6	5.0	20.3	140	52
15	37	44.1	2.9	1.4	4.3	16.3	140	69
25	53	52.7	3.3	1.4	4.0	17.6	140	79
35	68	60.6	3.6	1.4	4.1	20.3	140	90
45	82	67.8	3.9	1.3	4.4	23.0	140	100
55	94	74.3	4.1	1.3	4.8	25.3	140	110
65	106	80.3	4.3	1.3	5.1	27.4	140	118
75	117	85.8	4.4	1.3	5.5	29.2	140	126
85	127	90.8	4.5	1.2	5.8	30.7	140	133
95	136	95.4	4.6	1.2	6.1	32.0	140	139
105	145	99.6	4.7	1.2	6.3	33.1	140	145
115	152	103.5	4.7	1.2	6.6	34.2	140	150
125	160	107.0	4.7	1.2	6.8	35.1	140	155
135	166	110.3	4.8	1.2	7.0	35.9	140	159
145	173	113.2	4.8	1.2	7.2	36.6	140	163
155	178	116.0	4.8	1.2	7.4	37.3	140	167
165	184	118.5	4.8	1.2	7.5	37.9	140	170
175	188	120.8	4.8	1.2	7.7	38.4	140	173

R19. Northern Prairie States, Oak & Hickory

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.7	13.2	8.2	85	22
5	0	28.6	1.1	2.0	9.4	5.7	85	47
15	57	63.0	3.4	1.8	7.5	4.1	85	80
25	90	83.0	4.1	1.7	7.0	4.5	85	100
35	123	102.5	4.7	1.6	7.6	5.3	85	122
45	154	121.0	5.0	1.6	8.5	6.3	85	142
55	183	138.4	5.2	1.6	9.5	7.3	85	162
65	211	154.5	5.2	1.6	10.5	8.1	85	180
75	236	169.4	5.1	1.5	11.5	8.9	85	196
85	260	183.1	5.0	1.5	12.4	9.7	85	212
95	281	195.6	4.9	1.5	13.2	10.3	85	226
105	301	207.0	4.7	1.5	14.0	10.9	85	238
115	319	217.4	4.5	1.5	14.7	11.5	85	250
125	336	226.9	4.4	1.5	15.3	12.0	85	260
135	351	235.4	4.2	1.5	15.9	12.5	85	270
145	365	243.2	4.0	1.5	16.4	12.9	85	278
155	377	250.3	3.9	1.5	16.9	13.3	85	286
165	388	256.7	3.8	1.5	17.3	13.7	85	293
175	399	262.5	3.6	1.4	17.7	14.1	85	299

R20. Northern Prairie States, Pines

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.7	5.5	13.8	106	20
5	0	11.7	0.6	2.1	4.3	10.7	106	29
15	27	24.1	1.8	1.8	3.7	9.4	106	41
25	41	30.2	2.0	1.7	3.3	10.1	106	47
35	54	36.2	2.3	1.7	3.3	11.2	106	55
45	68	42.0	2.6	1.6	3.4	12.2	106	62
55	81	47.8	2.8	1.6	3.7	13.1	106	69
65	94	53.6	3.0	1.5	4.0	13.7	106	76
75	107	59.2	3.2	1.5	4.4	14.2	106	83
85	121	64.8	3.4	1.5	4.8	14.7	106	89
95	134	70.2	3.6	1.5	5.1	15.0	106	96
105	147	75.6	3.8	1.4	5.5	15.4	106	102
115	160	81.0	4.0	1.4	5.9	15.6	106	108
125	173	86.3	4.2	1.4	6.3	15.9	106	114
135	186	91.4	4.3	1.4	6.7	16.1	106	120
145	198	96.6	4.5	1.4	7.0	16.2	106	126
155	211	101.6	4.7	1.4	7.4	16.4	106	131
165	224	106.6	4.8	1.4	7.8	16.5	106	137
175	236	111.5	5.0	1.3	8.1	16.7	106	143

R21. Pacific Southwest, Douglas-fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.2	22.4	37.2	92	61
5	0	22.3	0.2	4.3	19.5	35.4	92	82
15	38	36.3	0.5	3.9	16.1	32.9	92	90
25	117	64.6	0.9	3.5	15.3	31.8	92	116
35	234	105.9	1.4	3.1	16.6	31.6	92	159
45	362	149.7	2.0	2.9	18.7	32.0	92	205
55	488	191.7	2.6	2.8	21.2	32.7	92	251
65	588	224.2	3.0	2.7	23.2	33.6	92	287
75	657	246.3	3.3	2.7	24.5	34.6	92	311
85	711	263.3	3.6	2.6	25.5	35.6	92	331
95	755	277.1	3.8	2.6	26.4	36.6	92	346
105	796	289.8	3.9	2.6	27.3	37.5	92	361
115	836	302.0	4.1	2.6	28.2	38.4	92	375
125	875	313.7	4.3	2.5	29.1	39.2	92	389
135	912	324.9	4.4	2.5	30.0	39.9	92	402
145	947	335.5	4.6	2.5	30.9	40.6	92	414
155	982	345.7	4.7	2.5	31.7	41.2	92	426
165	1015	355.3	4.8	2.5	32.6	41.8	92	437
175	1046	364.6	4.9	2.5	33.4	42.3	92	448

R22. Pacific Southwest, Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.9	9.9	31.7	80	44
5	0	48.2	2.0	4.2	7.3	28.4	80	90
15	63	73.3	6.1	4.1	5.3	24.6	80	113
25	112	92.3	7.7	4.0	4.8	23.4	80	132
35	178	117.4	9.8	4.0	5.3	23.5	80	160
45	245	141.8	11.8	4.0	6.1	24.3	80	188
55	301	161.8	13.5	4.0	6.8	25.5	80	212
65	357	181.2	15.1	3.9	7.6	26.8	80	235
75	409	199.0	16.6	3.9	8.3	28.1	80	256
85	455	214.2	17.9	3.9	8.9	29.4	80	274
95	497	227.8	19.0	3.9	9.5	30.6	80	291
105	532	239.0	20.0	3.9	9.9	31.7	80	304
115	563	249.0	20.8	3.9	10.3	32.6	80	317
125	591	257.7	21.5	3.9	10.7	33.5	80	327
135	616	265.2	22.2	3.9	11.0	34.4	80	337
145	637	271.6	22.7	3.9	11.3	35.1	80	345
155	654	276.9	23.1	3.9	11.5	35.8	80	351
165	668	281.1	23.5	3.9	11.7	36.4	80	357
175	682	285.2	23.8	3.9	11.8	37.0	80	362

R23. Pacific Southwest, Mixed Conifer

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.5	20.0	37.2	69	58
5	0	40.1	1.7	3.1	17.7	35.4	69	98
15	42	55.5	5.3	2.4	15.6	32.9	69	112
25	63	63.1	6.0	2.2	13.7	31.8	69	117
35	105	78.0	7.4	1.8	13.2	31.6	69	132
45	165	99.0	9.4	1.5	13.9	32.0	69	156
55	227	120.0	11.4	1.3	14.9	32.7	69	180
65	289	140.2	13.3	1.2	16.2	33.6	69	204
75	351	159.9	15.2	1.1	17.6	34.6	69	228
85	409	177.9	16.9	1.0	19.0	35.6	69	250
95	464	194.4	18.5	1.0	20.3	36.6	69	271
105	502	205.8	19.5	1.0	21.3	37.5	69	285
115	536	215.7	20.5	1.1	22.1	38.4	69	298
125	564	223.7	21.2	1.1	22.8	39.2	69	308
135	588	230.3	21.9	1.2	23.3	39.9	69	317
145	611	236.8	22.5	1.2	23.9	40.6	69	325
155	635	243.3	23.1	1.2	24.5	41.2	69	333
165	658	249.7	23.7	1.2	25.1	41.8	69	342
175	679	255.3	24.3	1.3	25.7	42.3	69	349

R24. Pacific Southwest, Ponderosa Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.5	18.3	37.2	84	56
5	0	40.1	1.4	3.1	16.3	35.4	84	96
15	16	45.9	4.4	2.8	13.6	32.9	84	100
25	38	54.2	5.2	2.5	12.0	31.8	84	106
35	79	68.7	6.5	2.0	11.7	31.6	84	121
45	128	86.0	8.2	1.7	12.2	32.0	84	140
55	180	104.0	9.9	1.5	13.0	32.7	84	161
65	231	121.2	11.5	1.3	14.1	33.6	84	182
75	280	137.4	13.0	1.2	15.2	34.6	84	201
85	327	152.5	14.5	1.1	16.3	35.6	84	220
95	372	166.6	15.8	1.0	17.5	36.6	84	237
105	414	179.5	17.0	1.0	18.6	37.5	84	254
115	453	191.2	18.2	1.0	19.6	38.4	84	268
125	488	201.7	19.2	1.0	20.5	39.2	84	282
135	520	211.0	20.0	1.1	21.4	39.9	84	293
145	549	219.1	20.8	1.1	22.1	40.6	84	304
155	573	226.1	21.5	1.1	22.8	41.2	84	313
165	593	231.8	22.0	1.2	23.3	41.8	84	320
175	609	236.3	22.4	1.2	23.8	42.3	84	326

R25. Pacific Southwest, Redwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	30.8	62.2	86	94
5	0	34.4	0.3	4.1	26.9	58.7	86	124
15	84	60.3	0.8	3.4	23.6	54.1	86	142
25	169	86.0	1.2	3.1	21.8	52.1	86	164
35	292	122.2	1.7	2.8	22.4	51.8	86	201
45	432	161.6	2.2	2.5	24.2	52.5	86	243
55	581	202.3	2.7	2.4	26.8	53.9	86	288
65	708	235.5	3.2	2.2	29.1	55.6	86	326
75	834	267.4	3.6	2.2	31.6	57.4	86	362
85	920	288.8	3.9	2.1	33.2	59.2	86	387
95	991	305.9	4.1	2.1	34.6	61.0	86	408
105	1058	321.6	4.4	2.0	35.9	62.7	86	427
115	1122	336.7	4.6	2.0	37.2	64.3	86	445
125	1185	351.1	4.8	2.0	38.6	65.7	86	462
135	1247	364.9	4.9	2.0	39.9	67.0	86	479
145	1306	378.0	5.1	1.9	41.3	68.3	86	495
155	1362	390.2	5.3	2.0	42.5	69.4	86	509
165	1415	401.5	5.4	2.0	43.7	70.4	86	523
175	1464	411.9	5.6	2.1	44.7	71.4	86	536

R26. Pacific Southwest, True Fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.8	20.2	37.2	138	58
5	0	24.3	1.9	3.1	17.7	35.4	138	82
15	10	28.9	5.8	3.0	14.2	32.9	138	85
25	33	38.7	7.7	2.7	12.3	31.8	138	93
35	59	49.9	9.9	2.5	11.4	31.6	138	105
45	91	63.1	12.6	2.4	11.2	32.0	138	121
55	133	80.4	16.0	2.2	11.9	32.7	138	143
65	197	106.3	21.2	2.1	13.9	33.6	138	177
75	278	137.4	27.4	1.9	16.7	34.6	138	218
85	359	167.7	33.4	1.8	19.5	35.6	138	258
95	435	194.9	38.9	1.8	22.1	36.6	138	294
105	502	217.8	43.4	1.7	24.4	37.5	138	325
115	561	237.7	47.4	1.7	26.3	38.4	138	351
125	614	254.7	50.8	1.6	28.1	39.2	138	374
135	659	269.1	53.7	1.6	29.5	39.9	138	394
145	698	281.1	56.0	1.6	30.7	40.6	138	410
155	729	290.7	58.0	1.6	31.7	41.2	138	423
165	754	298.0	59.4	1.6	32.5	41.8	138	433
175	771	303.2	60.5	1.6	33.0	42.3	138	441

R27. Pacific Northwest, Eastside, Douglas-fir & Larch

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.7	16.9	37.2	88	56
5	52	41.4	0.2	3.7	16.8	35.4	88	97
15	63	45.2	0.6	3.7	13.8	32.9	88	96
25	91	55.2	0.7	3.6	12.4	31.8	88	104
35	143	74.0	1.0	3.6	12.5	31.6	88	123
45	203	94.9	1.3	3.5	13.4	32.0	88	145
55	266	116.8	1.6	3.5	14.6	32.7	88	169
65	325	137.3	1.9	3.4	16.0	33.6	88	192
75	374	153.9	2.1	3.4	17.2	34.6	88	211
85	420	169.1	2.3	3.4	18.4	35.6	88	229
95	455	180.8	2.5	3.4	19.3	36.6	88	242
105	476	187.7	2.5	3.4	19.8	37.5	88	251
115	491	192.8	2.6	3.4	20.2	38.4	88	257
125	504	196.9	2.7	3.3	20.5	39.2	88	263
135	516	201.0	2.7	3.3	20.8	39.9	88	268
145	527	204.5	2.8	3.3	21.1	40.6	88	272
155	539	208.3	2.8	3.3	21.5	41.2	88	277
165	549	211.8	2.9	3.3	21.8	41.8	88	282
175	560	215.2	2.9	3.3	22.1	42.3	88	286

R28. Pacific Northwest, Eastside, Lodgepole Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.9	9.0	24.1	63	34
5	17	20.2	0.7	2.8	8.4	22.0	63	54
15	24	22.4	2.1	2.7	6.9	19.4	63	53
25	42	27.9	2.6	2.5	6.1	18.3	63	58
35	92	43.1	4.1	2.3	6.6	18.2	63	74
45	161	63.5	6.0	2.1	7.8	18.7	63	98
55	204	75.8	7.2	2.0	8.4	19.4	63	113
65	235	84.3	8.0	1.9	8.9	20.4	63	124
75	264	92.1	8.8	1.9	9.3	21.4	63	133
85	285	97.8	9.3	1.8	9.7	22.4	63	141
95	302	102.4	9.7	1.8	9.9	23.3	63	147
105	316	106.0	10.1	1.8	10.2	24.3	63	152
115	329	109.2	10.4	1.8	10.4	25.2	63	157
125	337	111.5	10.6	1.8	10.5	26.0	63	160
135	344	113.3	10.8	1.8	10.7	26.7	63	163
145	351	115.0	10.9	1.8	10.8	27.5	63	166
155	358	116.8	11.1	1.8	10.9	28.1	63	169
165	365	118.6	11.3	1.8	11.1	28.7	63	171
175	372	120.4	11.4	1.8	11.2	29.3	63	174

R29. Pacific Northwest, Eastside, Ponderosa Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.1	8.9	24.1	70	34
5	17	20.2	0.8	3.1	8.4	22.0	70	54
15	34	25.4	2.4	2.9	7.3	19.4	70	57
25	56	32.2	3.1	2.8	6.7	18.3	70	63
35	84	40.8	3.9	2.7	6.7	18.2	70	72
45	119	51.2	4.9	2.5	7.1	18.7	70	84
55	150	60.5	5.7	2.4	7.6	19.4	70	96
65	175	67.6	6.4	2.4	8.0	20.4	70	105
75	196	73.5	7.0	2.3	8.3	21.4	70	112
85	214	78.6	7.5	2.3	8.6	22.4	70	119
95	230	83.0	7.9	2.3	9.0	23.3	70	125
105	246	87.3	8.3	2.3	9.3	24.3	70	131
115	262	91.5	8.7	2.2	9.7	25.2	70	137
125	277	95.7	9.1	2.2	10.0	26.0	70	143
135	293	99.9	9.5	2.2	10.4	26.7	70	149
145	309	104.0	9.9	2.2	10.8	27.5	70	154
155	324	108.1	10.3	2.2	11.2	28.1	70	160
165	340	112.1	10.7	2.1	11.6	28.7	70	165
175	356	116.1	11.0	2.1	12.0	29.3	70	171

R30. Pacific Northwest, Eastside, True Fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.1	14.7	37.2	142	53
5	24	34.5	2.6	2.8	14.0	35.4	142	89
15	35	39.4	7.9	2.7	11.8	32.9	142	95
25	44	43.3	8.6	2.7	10.2	31.8	142	97
35	70	54.3	10.8	2.6	9.9	31.6	142	109
45	108	70.4	14.0	2.5	10.5	32.0	142	129
55	154	89.0	17.7	2.4	11.7	32.7	142	153
65	196	105.7	21.1	2.4	12.8	33.6	142	176
75	231	119.4	23.8	2.3	13.9	34.6	142	194
85	259	130.2	26.0	2.3	14.7	35.6	142	209
95	281	138.5	27.6	2.3	15.4	36.6	142	220
105	298	145.1	28.9	2.2	15.9	37.5	142	230
115	313	150.6	30.0	2.2	16.3	38.4	142	238
125	327	156.0	31.1	2.2	16.8	39.2	142	245
135	342	161.5	32.2	2.2	17.3	39.9	142	253
145	357	166.8	33.3	2.2	17.9	40.6	142	261
155	372	172.2	34.3	2.2	18.4	41.2	142	268
165	386	177.5	35.4	2.2	18.9	41.8	142	276
175	401	182.7	36.4	2.2	19.5	42.3	142	283

R31. Pacific Northwest, Westside, Douglas-fir, high productivity sites (greater than 165 cu. ft./ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.4	34.0	27.5	90	63
5	0	22.3	0.1	4.0	29.4	23.7	90	80
15	20	29.5	0.4	3.9	22.9	20.7	90	77
25	132	69.7	0.9	3.6	21.6	21.2	90	117
35	348	145.0	2.0	3.3	25.2	23.3	90	199
45	564	216.4	2.9	3.1	29.5	26.0	90	278
55	768	281.2	3.8	3.1	33.9	28.9	90	351
65	941	333.6	4.5	3.0	37.6	31.8	90	410
75	1080	374.4	5.1	3.0	40.5	34.5	90	457
85	1199	408.4	5.5	2.9	43.1	37.0	90	497
95	1302	437.1	5.9	2.9	45.4	39.3	90	531
105	1393	461.7	6.3	2.9	47.4	41.5	90	560

R32. Pacific Northwest, Westside, Douglas-fir, high productivity sites (greater than 165 cu. ft./ac/yr), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.4	37.3	27.5	90	66
5	0	22.3	0.1	4.0	32.3	23.7	90	82
15	20	29.5	0.4	3.9	25.0	20.7	90	80
25	170	83.3	1.1	3.5	24.5	21.2	90	134
35	446	177.8	2.4	3.2	29.6	23.3	90	236
45	719	265.8	3.6	3.1	35.3	26.0	90	334
55	924	328.6	4.5	3.0	39.2	28.9	90	404
65	1086	376.2	5.1	3.0	42.3	31.8	90	458
75	1226	415.8	5.6	2.9	45.0	34.5	90	504
85	1347	449.3	6.1	2.9	47.4	37.0	90	543
95	1452	477.7	6.5	2.9	49.6	39.3	90	576
105	1544	502.0	6.8	2.9	51.6	41.5	90	605

R33. Pacific Northwest, Westside, Douglas-fir medium productivity sites (between 120 and 164 cu. ft./ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.5	27.8	27.5	90	57
5	0	22.3	0.2	4.0	24.1	23.7	90	74
15	31	33.6	0.5	3.8	19.4	20.7	90	78
25	63	45.3	0.6	3.7	16.3	21.2	90	87
35	228	103.6	1.4	3.4	19.0	23.3	90	151
45	396	161.3	2.2	3.2	22.5	26.0	90	215
55	557	214.4	2.9	3.1	26.1	28.9	90	275
65	707	262.1	3.6	3.1	29.6	31.8	90	330
75	831	300.5	4.1	3.0	32.6	34.5	90	375
85	930	330.4	4.5	3.0	34.9	37.0	90	410
95	1014	355.2	4.8	3.0	36.9	39.3	90	439
105	1086	376.2	5.1	3.0	38.6	41.5	90	464

R34. Pacific Northwest, Westside, Douglas-fir, medium productivity sites (between 120 and 164 cu.ft./ac/yr), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.5	30.6	27.5	90	60
5	0	22.3	0.2	4.0	26.5	23.7	90	77
15	31	33.6	0.5	3.8	21.2	20.7	90	80
25	79	50.8	0.7	3.7	18.2	21.2	90	95
35	273	119.4	1.6	3.4	21.5	23.3	90	169
45	494	193.7	2.6	3.2	26.4	26.0	90	252
55	689	256.3	3.5	3.1	30.8	28.9	90	323
65	836	301.9	4.1	3.0	34.0	31.8	90	375
75	955	337.8	4.6	3.0	36.6	34.5	90	416
85	1053	366.5	5.0	3.0	38.7	37.0	90	450
95	1137	390.7	5.3	2.9	40.6	39.3	90	479
105	1210	411.4	5.6	2.9	42.2	41.5	90	504

R35. Pacific Northwest, Westside, Fir & Spruce, high productivity sites

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.2	18.1	29.5	140	49
5	0	24.3	3.2	3.5	15.8	27.0	140	74
15	55	48.0	9.6	3.1	14.3	25.2	140	100
25	112	71.7	14.3	2.9	13.8	25.6	140	128
35	173	96.7	19.3	2.8	14.1	27.1	140	160
45	236	121.3	24.2	2.7	14.8	28.9	140	192
55	297	144.6	28.8	2.6	15.9	30.8	140	223
65	355	166.1	33.1	2.5	17.0	32.6	140	251
75	409	185.5	37.0	2.5	18.2	34.2	140	277
85	458	202.8	40.4	2.5	19.3	35.6	140	301
95	502	218.0	43.5	2.4	20.4	36.8	140	321
105	541	231.1	46.1	2.4	21.3	37.9	140	339
115	575	242.3	48.3	2.4	22.2	38.9	140	354
125	604	251.7	50.2	2.4	22.9	39.8	140	367
135	629	259.5	51.7	2.4	23.5	40.6	140	378
145	648	265.8	53.0	2.4	24.0	41.3	140	386
155	664	270.6	54.0	2.3	24.4	41.9	140	393
165	675	274.1	54.7	2.3	24.7	42.5	140	398
175	683	276.5	55.1	2.3	24.9	43.0	140	402

R36. Pacific Northwest, Westside, Fir & Spruce, medium productivity sites

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.3	10.9	29.5	139	42
5	0	24.3	2.3	3.5	9.7	27.0	139	67
15	24	34.9	7.0	3.3	8.6	25.2	139	79
25	50	45.7	9.1	3.1	8.1	25.6	139	92
35	77	57.3	11.4	3.0	8.1	27.1	139	107
45	105	68.9	13.7	2.9	8.3	28.9	139	123
55	132	80.1	16.0	2.9	8.8	30.8	139	138
65	158	90.5	18.0	2.8	9.3	32.6	139	153
75	182	100.1	20.0	2.8	9.8	34.2	139	167
85	204	108.8	21.7	2.7	10.4	35.6	139	179
95	223	116.5	23.2	2.7	10.9	36.8	139	190
105	241	123.3	24.6	2.7	11.4	37.9	139	200
115	256	129.1	25.7	2.6	11.8	38.9	139	208
125	269	134.0	26.7	2.6	12.2	39.8	139	215
135	280	138.1	27.5	2.6	12.5	40.6	139	221
145	288	141.4	28.2	2.6	12.8	41.3	139	226
155	295	144.0	28.7	2.6	13.0	41.9	139	230
165	300	145.9	29.1	2.6	13.1	42.5	139	233
175	304	147.2	29.3	2.6	13.2	43.0	139	235

R37. Pacific Northwest, Westside, Hardwood Mix

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.2	17.0	9.3	80	28
5	0	21.8	1.1	4.4	11.7	3.9	80	43
15	368	129.2	3.4	3.0	12.6	4.5	80	153
25	509	165.8	4.4	2.8	12.3	6.2	80	192
35	667	204.3	5.4	2.7	13.6	7.6	80	234
45	828	241.1	6.4	2.6	15.4	8.6	80	274
55	976	272.5	7.2	2.5	17.2	9.4	80	309
65	1091	295.4	7.8	2.5	18.5	10.1	80	334
75	1157	308.0	8.1	2.4	19.3	10.7	80	349
85	1163	309.1	8.2	2.4	19.3	11.1	80	350
95	1163	309.1	8.2	2.4	19.3	11.5	80	351
105	1163	309.1	8.2	2.4	19.3	11.9	80	351
115	1163	309.1	8.2	2.4	19.3	12.2	80	351
125	1163	309.1	8.2	2.4	19.3	12.4	80	351
135	1163	309.1	8.2	2.4	19.3	12.6	80	352
145	1163	309.1	8.2	2.4	19.3	12.9	80	352
155	1163	309.1	8.2	2.4	19.3	13.0	80	352
165	1163	309.1	8.2	2.4	19.3	13.2	80	352
175	1163	309.1	8.2	2.4	19.3	13.4	80	352

R38. Pacific Northwest, Westside, Red Alder, high productivity sites

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	24.6	9.3	80	35
5	0	21.8	0.5	4.0	17.0	3.9	80	47
15	98	52.0	1.4	3.3	11.5	4.5	80	73
25	240	93.7	2.5	2.9	11.7	6.2	80	117
35	396	136.6	3.6	2.6	14.2	7.6	80	165
45	530	171.2	4.5	2.5	16.8	8.6	80	204
55	647	199.6	5.3	2.4	19.2	9.4	80	236
65	751	223.7	5.9	2.3	21.3	10.1	80	263
75	846	244.8	6.5	2.3	23.2	10.7	80	288
85	936	264.0	7.0	2.2	25.0	11.1	80	309
95	1023	281.9	7.4	2.2	26.7	11.5	80	330
105	1110	299.0	7.9	2.2	28.3	11.9	80	349
115	1196	315.4	8.3	2.2	29.9	12.2	80	368
125	1283	331.2	8.7	2.1	31.4	12.4	80	386
135	1369	346.3	9.1	2.1	32.8	12.6	80	403
145	1455	360.9	9.5	2.1	34.2	12.9	80	420
155	1539	374.6	9.9	2.1	35.5	13.0	80	435
165	1618	386.9	10.2	2.1	36.7	13.2	80	449
175	1687	397.5	10.5	2.0	37.7	13.4	80	461

R39. Pacific Northwest, Westside, Red Alder, medium productivity sites

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.0	23.3	9.3	80	34
5	0	21.8	0.5	4.0	16.1	3.9	80	46
15	118	58.1	1.5	3.2	11.7	4.5	80	79
25	213	86.1	2.3	2.9	10.9	6.2	80	108
35	331	119.2	3.1	2.7	12.5	7.6	80	145
45	452	151.2	4.0	2.6	14.8	8.6	80	181
55	563	179.4	4.7	2.5	17.2	9.4	80	213
65	661	203.1	5.4	2.4	19.3	10.1	80	240
75	751	223.7	5.9	2.3	21.2	10.7	80	264
85	838	243.2	6.4	2.3	23.1	11.1	80	286
95	926	261.9	6.9	2.3	24.8	11.5	80	307
105	1013	279.9	7.4	2.2	26.5	11.9	80	328
115	1100	297.2	7.8	2.2	28.2	12.2	80	348
125	1188	313.9	8.3	2.2	29.7	12.4	80	366
135	1275	329.9	8.7	2.1	31.3	12.6	80	385
145	1363	345.3	9.1	2.1	32.7	12.9	80	402
155	1450	360.1	9.5	2.1	34.1	13.0	80	419
165	1538	374.4	9.9	2.1	35.5	13.2	80	435
175	1625	388.1	10.2	2.1	36.8	13.4	80	451

R40. Pacific Northwest, Westside, Western Hemlock, high productivity sites (greater than 225 cu.ft./ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.1	39.2	27.5	157	68
5	0	27.2	2.4	3.9	34.0	23.7	157	91
15	80	53.6	7.2	3.4	28.3	20.7	157	113
25	154	77.3	10.4	3.1	24.5	21.2	157	137
35	502	181.4	24.5	2.6	30.2	23.3	157	262
45	873	280.5	37.8	2.4	36.7	26.0	157	383
55	1176	353.3	47.6	2.2	41.5	28.9	157	474
65	1437	410.4	55.3	2.2	45.3	31.8	157	545
75	1649	453.6	61.2	2.3	48.3	34.5	157	600
85	1796	481.8	65.0	2.4	50.1	37.0	157	636
95	1925	505.4	68.1	2.5	51.8	39.3	157	667
105	2032	524.3	70.7	2.6	53.1	41.5	157	692

R41. Pacific Northwest, Westside, Western Hemlock, medium productivity sites (between 120 and 224 cu.ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	M^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.1	34.0	27.5	157	63
5	0	27.2	1.9	3.9	29.5	23.7	157	86
15	48	42.9	5.8	3.5	23.9	20.7	157	97
25	101	60.2	8.1	3.3	20.4	21.2	157	113
35	334	132.6	17.9	2.8	23.7	23.3	157	200
45	616	213.3	28.8	2.5	28.8	26.0	157	299
55	880	282.4	38.1	2.3	33.5	28.9	157	385
65	1112	338.6	45.7	2.3	37.6	31.8	157	456
75	1307	382.6	51.6	2.2	40.8	34.5	157	512
85	1456	414.4	55.9	2.2	43.1	37.0	157	553
95	1574	438.7	59.1	2.2	44.9	39.3	157	584
105	1682	460.0	62.0	2.3	46.6	41.5	157	612

R42. Rocky Mountain, North, Douglas-fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	M^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.7	9.2	37.2	95	47
5	0	20.2	1.3	3.5	8.4	35.4	95	69
15	9	24.4	3.9	3.3	7.2	32.9	95	72
25	21	30.3	4.8	3.0	6.4	31.8	95	76
35	46	41.9	6.7	2.7	6.2	31.6	95	89
45	93	63.6	10.1	2.3	6.8	32.0	95	115
55	152	89.6	14.2	2.1	7.8	32.7	95	146
65	204	111.7	17.7	1.9	8.7	33.6	95	174
75	247	129.5	20.6	1.8	9.5	34.6	95	196
85	285	145.0	23.0	1.7	10.1	35.6	95	215
95	320	158.7	25.2	1.7	10.8	36.6	95	233
105	350	170.4	27.1	1.6	11.3	37.5	95	248
115	377	180.6	28.7	1.6	11.8	38.4	95	261
125	401	189.7	30.1	1.6	12.2	39.2	95	273
135	424	198.0	31.5	1.5	12.7	39.9	95	284
145	446	205.8	32.7	1.5	13.1	40.6	95	294
155	467	213.3	33.9	1.5	13.5	41.2	95	303
165	485	219.7	34.9	1.5	13.8	41.8	95	312
175	499	224.6	35.7	1.5	14.1	42.3	95	318

R43. Rocky Mountain, North, Fir & Spruce

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.8	13.6	37.2	138	52
5	0	16.1	1.7	3.5	12.3	35.4	138	69
15	13	20.9	5.3	3.2	10.6	32.9	138	73
25	25	25.3	6.4	3.0	9.3	31.8	138	76
35	56	36.8	9.3	2.7	9.1	31.6	138	89
45	116	58.2	14.6	2.3	10.1	32.0	138	117
55	193	85.5	21.5	2.1	12.0	32.7	138	154
65	269	111.0	27.9	1.9	13.8	33.6	138	188
75	331	131.5	33.1	1.8	15.3	34.6	138	216
85	381	147.7	37.1	1.7	16.5	35.6	138	239
95	418	159.2	40.0	1.7	17.3	36.6	138	255
105	446	168.1	42.3	1.7	18.0	37.5	138	268
115	467	174.6	43.9	1.7	18.4	38.4	138	277
125	483	179.5	45.1	1.6	18.7	39.2	138	284
135	497	183.7	46.2	1.6	19.0	39.9	138	290
145	508	187.1	47.0	1.6	19.2	40.6	138	296
155	516	189.4	47.6	1.6	19.4	41.2	138	299
165	521	190.9	48.0	1.6	19.4	41.8	138	302
175	524	192.0	48.3	1.6	19.5	42.3	138	304

R44. Rocky Mountain, North, Lodgepole Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.6	6.5	24.1	66	31
5	0	20.3	1.7	2.9	5.9	22.0	66	53
15	15	24.5	5.2	2.6	5.2	19.4	66	57
25	34	29.8	6.3	2.4	4.7	18.3	66	61
35	62	37.6	7.9	2.1	4.6	18.2	66	70
45	123	53.8	11.3	1.8	5.0	18.7	66	91
55	189	71.1	15.0	1.6	5.6	19.4	66	113
65	236	83.1	17.5	1.4	6.0	20.4	66	128
75	281	94.3	19.9	1.3	6.4	21.4	66	143
85	322	104.4	22.0	1.3	6.8	22.4	66	157
95	360	113.6	24.0	1.2	7.2	23.3	66	169
105	395	121.8	25.7	1.2	7.5	24.3	66	180
115	426	129.0	27.2	1.2	7.9	25.2	66	190
125	452	134.9	28.4	1.1	8.1	26.0	66	199
135	470	138.9	29.3	1.1	8.3	26.7	66	204
145	477	140.5	29.6	1.1	8.3	27.5	66	207

R45. Rocky Mountain, North, Ponderosa Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.8	7.6	24.1	70	32
5	0	14.6	0.6	3.2	6.9	22.0	70	47
15	12	18.7	1.8	3.0	6.1	19.4	70	49
25	30	24.8	2.4	2.7	5.7	18.3	70	54
35	63	35.6	3.4	2.4	5.9	18.2	70	66
45	101	47.8	4.6	2.2	6.4	18.7	70	80
55	132	57.8	5.6	2.0	6.8	19.4	70	92
65	161	66.9	6.5	1.9	7.3	20.4	70	103
75	187	74.9	7.2	1.8	7.7	21.4	70	113
85	211	82.1	7.9	1.8	8.1	22.4	70	122
95	231	88.2	8.5	1.7	8.4	23.3	70	130
105	249	93.6	9.0	1.7	8.7	24.3	70	137
115	265	98.4	9.5	1.7	9.1	25.2	70	144
125	279	102.5	9.9	1.7	9.3	26.0	70	149
135	289	105.5	10.2	1.6	9.5	26.7	70	154
145	298	108.0	10.4	1.6	9.7	27.5	70	157
155	306	110.4	10.7	1.6	9.8	28.1	70	161
165	313	112.4	10.9	1.6	10.0	28.7	70	164
175	318	113.8	11.0	1.6	10.1	29.3	70	166

R46. Rocky Mountain, South, Douglas-fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.3	6.9	37.2	90	44
5	0	20.2	1.3	4.2	6.3	35.4	90	67
15	9	24.7	3.9	3.3	5.7	32.9	90	71
25	15	27.2	4.3	2.9	5.1	31.8	90	71
35	21	30.4	4.8	2.6	4.7	31.6	90	74
45	33	35.8	5.7	2.1	4.7	32.0	90	80
55	51	44.2	7.0	1.6	4.9	32.7	90	90
65	75	55.3	8.8	1.2	5.4	33.6	90	104
75	100	66.6	10.6	1.0	6.1	34.6	90	119
85	121	76.1	12.1	0.8	6.6	35.6	90	131
95	140	84.5	13.4	0.7	7.1	36.6	90	142
105	156	91.6	14.5	0.7	7.5	37.5	90	152
115	169	97.2	15.4	0.6	7.8	38.4	90	159
125	181	101.9	16.2	0.6	8.1	39.2	90	166
135	190	105.9	16.8	0.6	8.3	39.9	90	171
145	197	109.1	17.3	0.5	8.5	40.6	90	176
155	204	111.9	17.8	0.6	8.7	41.2	90	180
165	209	114.1	18.1	0.6	8.9	41.8	90	183
175	214	116.1	18.4	0.6	9.0	42.3	90	186

R47. Rocky Mountain, South, Fir & Spruce

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.5	7.9	37.2	138	46
5	0	16.1	1.5	3.6	7.2	35.4	138	64
15	4	17.7	4.5	3.4	6.1	32.9	138	65
25	14	21.3	5.4	3.1	5.4	31.8	138	67
35	36	29.5	7.4	2.6	5.3	31.6	138	76
45	56	36.7	9.2	2.3	5.2	32.0	138	85
55	82	46.3	11.6	2.0	5.5	32.7	138	98
65	117	58.6	14.7	1.7	6.1	33.6	138	115
75	149	69.9	17.6	1.6	6.7	34.6	138	130
85	182	81.4	20.5	1.4	7.3	35.6	138	146
95	212	91.7	23.1	1.3	8.0	36.6	138	161
105	248	104.0	26.2	1.2	8.8	37.5	138	178
115	282	115.3	29.0	1.2	9.5	38.4	138	193
125	316	126.5	31.8	1.1	10.3	39.2	138	209
135	350	137.8	34.7	1.1	11.1	39.9	138	225
145	376	146.1	36.7	1.0	11.7	40.6	138	236
155	401	153.9	38.7	1.0	12.3	41.2	138	247
165	427	162.1	40.8	1.0	12.9	41.8	138	258
175	447	168.4	42.4	0.9	13.4	42.3	138	267

R48. Rocky Mountain, South, High Elevation

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.6	6.4	37.2	90	44
5	0	14.6	1.1	3.0	5.8	35.4	90	60
15	4	16.6	3.2	2.9	4.9	32.9	90	60
25	14	21.0	4.0	2.6	4.4	31.8	90	64
35	36	31.1	6.0	2.3	4.3	31.6	90	75
45	56	39.8	7.6	2.1	4.3	32.0	90	86
55	82	51.3	9.9	1.9	4.6	32.7	90	100
65	117	65.8	12.7	1.7	5.2	33.6	90	119
75	149	78.8	15.1	1.6	5.7	34.6	90	136
85	182	91.9	17.7	1.5	6.3	35.6	90	153
95	212	103.4	19.9	1.4	6.8	36.6	90	168
105	248	116.8	22.4	1.4	7.5	37.5	90	186
115	282	128.8	24.8	1.3	8.1	38.4	90	201
125	316	140.6	27.0	1.3	8.7	39.2	90	217
135	350	152.3	29.3	1.2	9.3	39.9	90	232
145	376	160.6	30.9	1.2	9.8	40.6	90	243
155	401	168.3	32.3	1.2	10.2	41.2	90	253
165	427	176.4	33.9	1.2	10.7	41.8	90	264
175	447	182.6	35.1	1.2	11.0	42.3	90	272

R49. Rocky Mountain, South, Lodgepole Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.4	9.4	24.1	63	34
5	0	20.3	1.4	3.0	8.6	22.0	63	55
15	0	20.3	4.3	3.0	7.2	19.4	63	54
25	9	22.7	4.8	2.7	6.4	18.3	63	55
35	25	27.1	5.7	2.4	6.0	18.2	63	59
45	49	33.9	7.1	2.0	6.0	18.7	63	68
55	88	44.4	9.4	1.7	6.5	19.4	63	81
65	132	56.2	11.8	1.4	7.2	20.4	63	97
75	179	68.5	14.5	1.2	8.1	21.4	63	114
85	229	81.3	17.2	1.1	9.0	22.4	63	131
95	276	93.0	19.6	1.0	10.0	23.3	63	147
105	314	102.4	21.6	0.9	10.7	24.3	63	160
115	346	110.0	23.2	0.9	11.4	25.2	63	171
125	370	115.8	24.4	0.8	11.8	26.0	63	179
135	387	119.8	25.3	0.8	12.1	26.7	63	185
145	395	121.7	25.7	0.8	12.2	27.5	63	188

R50. Rocky Mountain, South, Ponderosa Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.5	5.3	24.1	71	30
5	0	14.6	0.6	3.5	4.9	22.0	71	46
15	14	19.2	1.9	2.9	4.5	19.4	71	48
25	18	20.6	2.0	2.7	4.0	18.3	71	48
35	25	22.9	2.2	2.5	3.7	18.2	71	50
45	38	27.3	2.6	2.2	3.7	18.7	71	54
55	56	33.3	3.2	1.9	3.9	19.4	71	62
65	74	39.2	3.8	1.7	4.1	20.4	71	69
75	91	44.7	4.3	1.5	4.4	21.4	71	76
85	107	49.8	4.8	1.4	4.7	22.4	71	83
95	122	54.6	5.3	1.3	5.0	23.3	71	90
105	139	60.1	5.8	1.2	5.3	24.3	71	97
115	153	64.4	6.2	1.2	5.6	25.2	71	103
125	168	68.9	6.7	1.1	5.9	26.0	71	109
135	183	73.6	7.1	1.1	6.2	26.7	71	115
145	198	78.3	7.6	1.0	6.6	27.5	71	121
155	213	82.8	8.0	1.0	6.9	28.1	71	127
165	227	87.0	8.4	0.9	7.2	28.7	71	132
175	240	90.8	8.8	0.9	7.5	29.3	71	137

R51. South Central, Lowland Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.7	7.3	6.0	149	14
5	0	29.3	1.5	1.7	4.9	2.4	149	40
10	11	34.7	2.7	1.7	4.0	2.4	149	45
15	23	40.2	3.1	1.7	3.5	3.0	149	51
20	39	47.9	3.6	1.6	3.6	3.8	149	60
25	54	54.9	4.0	1.6	3.8	4.4	149	69
30	71	62.9	4.4	1.6	4.2	5.0	149	78
35	87	70.3	4.7	1.6	4.5	5.5	149	87
40	104	77.9	5.0	1.6	5.0	6.0	149	95
45	121	85.9	5.3	1.5	5.5	6.4	149	105
50	138	93.4	5.4	1.5	5.9	6.8	149	113
55	155	100.9	5.6	1.5	6.4	7.2	149	122
60	172	108.8	5.6	1.5	6.9	7.5	149	130
65	189	116.1	5.7	1.5	7.3	7.8	149	138
70	205	123.3	5.6	1.5	7.8	8.1	149	146
75	219	129.4	5.6	1.5	8.2	8.4	149	153
80	234	135.9	5.5	1.5	8.6	8.6	149	160
85	249	142.2	5.4	1.5	9.0	8.9	149	167
90	264	148.4	5.3	1.5	9.4	9.1	149	174

R52. South Central, Natural Pine, high productivity sites (greater than 120 cubic feet/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.1	7.9	12.2	94	21
5	0	18.5	0.8	4.1	6.3	6.5	94	36
10	20	25.9	1.2	3.7	5.6	6.4	94	43
15	47	35.8	1.6	3.4	5.3	7.5	94	54
20	76	46.1	2.0	3.2	5.3	8.7	94	65
25	108	57.6	2.5	3.0	5.6	9.8	94	79
30	140	68.7	3.0	2.9	5.9	10.7	94	91
35	173	80.0	3.4	2.8	6.4	11.5	94	104
40	205	90.9	3.7	2.7	6.9	12.2	94	116
45	238	101.8	3.9	2.6	7.5	12.7	94	129
50	268	111.6	4.1	2.6	8.0	13.2	94	139
55	297	121.3	4.1	2.5	8.6	13.7	94	150
60	327	130.8	4.0	2.5	9.2	14.1	94	160
65	356	140.0	3.8	2.4	9.7	14.4	94	170
70	379	147.2	3.7	2.4	10.2	14.7	94	178
75	402	154.4	3.4	2.4	10.7	15.0	94	186
80	423	160.8	3.2	2.3	11.1	15.2	94	193
85	444	167.2	2.9	2.3	11.5	15.5	94	199
90	462	172.5	2.6	2.3	11.8	15.7	94	205

R53. South Central, Natural Pine, medium productivity sites (between 50 and 119 cu.ft./ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.2	6.9	12.2	97	20
5	0	18.5	0.7	4.1	5.5	6.5	97	35
10	18	25.2	1.1	3.8	4.9	6.4	97	41
15	35	31.3	1.4	3.6	4.6	7.5	97	48
20	56	38.9	1.7	3.4	4.5	8.7	97	57
25	80	47.4	2.1	3.2	4.6	9.8	97	67
30	105	56.2	2.5	3.1	4.9	10.7	97	77
35	131	65.4	2.8	2.9	5.3	11.5	97	88
40	161	75.7	3.2	2.8	5.8	12.2	97	100
45	186	84.4	3.5	2.8	6.2	12.7	97	110
50	212	93.2	3.8	2.7	6.7	13.2	97	120
55	236	101.2	3.9	2.6	7.2	13.7	97	129
60	260	109.2	4.0	2.6	7.7	14.1	97	138
65	282	116.1	4.1	2.5	8.1	14.4	97	145
70	303	123.2	4.1	2.5	8.5	14.7	97	153
75	322	129.1	4.0	2.5	8.9	15.0	97	160
80	339	134.7	4.0	2.4	9.3	15.2	97	166
85	355	139.7	3.9	2.4	9.6	15.5	97	171
90	369	144.1	3.7	2.4	9.9	15.7	97	176

R54. South Central, Oak-Pine, high productivity sites (greater than 120 cubic feet/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.3	8.1	10.3	82	20
5	0	19.9	1.1	3.8	6.5	5.8	82	37
10	23	29.8	1.7	3.5	6.0	5.9	82	47
15	40	37.4	2.1	3.4	5.6	6.8	82	55
20	56	44.6	2.5	3.3	5.4	7.7	82	64
25	75	52.5	2.9	3.2	5.5	8.6	82	73
30	97	62.0	3.5	3.1	5.7	9.2	82	83
35	119	71.4	3.9	3.0	6.1	9.8	82	94
40	142	81.0	4.4	2.9	6.6	10.2	82	105
45	164	90.5	4.8	2.8	7.1	10.6	82	116
50	187	99.9	5.1	2.8	7.6	11.0	82	126
55	210	109.3	5.3	2.7	8.2	11.3	82	137
60	234	119.0	5.3	2.7	8.8	11.5	82	147
65	257	128.6	5.3	2.7	9.5	11.8	82	158
70	282	138.6	5.1	2.6	10.2	12.0	82	168
75	307	148.5	4.7	2.6	10.8	12.1	82	179
80	330	157.6	4.3	2.6	11.5	12.3	82	188
85	353	166.3	3.8	2.5	12.1	12.5	82	197
90	374	174.5	3.3	2.5	12.7	12.6	82	205

R55. South Central, Oak-Pine, medium productivity sites (between 50 and 119 cu.ft./ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.3	7.0	10.3	82	19
5	0	19.9	0.9	3.8	5.6	5.8	82	36
10	10	24.6	1.4	3.7	5.0	5.9	82	40
15	24	30.7	1.7	3.5	4.6	6.8	82	47
20	38	36.8	2.1	3.4	4.5	7.7	82	54
25	54	43.4	2.4	3.3	4.5	8.6	82	62
30	69	49.8	2.8	3.2	4.6	9.2	82	70
35	88	58.2	3.3	3.1	5.0	9.8	82	79
40	108	66.8	3.7	3.0	5.4	10.2	82	89
45	129	75.8	4.1	2.9	5.9	10.6	82	99
50	149	83.9	4.5	2.9	6.4	11.0	82	109
55	168	92.1	4.8	2.8	6.9	11.3	82	118
60	189	100.7	5.1	2.8	7.5	11.5	82	128
65	209	109.0	5.3	2.7	8.0	11.8	82	137
70	229	117.1	5.3	2.7	8.6	12.0	82	146
75	247	124.2	5.3	2.7	9.1	12.1	82	153
80	262	130.6	5.3	2.7	9.5	12.3	82	160
85	275	135.5	5.2	2.6	9.9	12.5	82	166
90	283	139.0	5.1	2.6	10.1	12.6	82	169

R56. South Central, Planted Pine, high productivity sites (greater than 120 cubic feet/ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.8	5.0	12.2	96	19
5	0	14.2	1.2	4.0	3.9	6.5	96	30
10	48	32.8	1.2	3.9	3.8	6.4	96	48
15	147	69.5	2.5	3.8	4.6	7.5	96	88
20	245	103.7	3.7	3.7	5.5	8.7	96	125
25	315	126.8	4.5	3.7	6.0	9.8	96	151
30	347	137.0	4.9	3.7	6.1	10.7	96	162
35	352	138.3	4.9	3.7	6.0	11.5	96	164
40	355	139.4	5.0	3.7	5.9	12.2	96	166
45	359	140.5	5.0	3.7	5.8	12.7	96	168
50	362	141.6	5.0	3.7	5.8	13.2	96	169

R57. South Central, Planted Pine, high productivity sites (greater than 120 cubic feet/ac/yr), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.8	6.1	12.2	96	20
5	0	14.2	1.7	4.0	4.8	6.5	96	31
10	78	44.4	1.6	3.9	4.9	6.4	96	61
15	227	97.7	3.5	3.8	6.2	7.5	96	119
20	350	137.7	4.9	3.7	7.2	8.7	96	162
25	429	162.0	5.8	3.7	7.7	9.8	96	189
30	462	171.6	6.1	3.7	7.7	10.7	96	200
35	464	172.2	6.1	3.7	7.5	11.5	96	201
40	466	172.8	6.2	3.7	7.3	12.2	96	202
45	468	173.4	6.2	3.7	7.2	12.7	96	203
50	470	174.0	6.2	3.7	7.1	13.2	96	204

R58. South Central, Planted Pine, medium productivity sites (between 50 and 119 cu.ft./ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.9	4.0	12.2	96	18
5	0	14.2	0.9	4.0	3.2	6.5	96	29
10	28	25.1	0.9	3.9	3.0	6.4	96	39
15	95	50.6	1.8	3.8	3.5	7.5	96	67
20	165	76.0	2.7	3.8	4.1	8.7	96	95
25	219	95.0	3.4	3.8	4.5	9.8	96	117
30	252	106.2	3.8	3.7	4.8	10.7	96	129
35	260	108.9	3.9	3.7	4.7	11.5	96	133
40	263	109.7	3.9	3.7	4.6	12.2	96	134
45	265	110.5	3.9	3.7	4.6	12.7	96	136
50	268	111.4	4.0	3.7	4.5	13.2	96	137

R59. South Central, Planted Pine, medium productivity sites (between 50 and 119 cu.ft./ac/yr), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.8	5.1	12.2	96	19
5	0	14.2	1.3	4.0	4.0	6.5	96	30
10	45	31.7	1.1	3.9	3.8	6.4	96	47
15	152	71.4	2.5	3.8	4.7	7.5	96	90
20	255	107.1	3.8	3.7	5.6	8.7	96	129
25	321	128.7	4.6	3.7	6.1	9.8	96	153
30	354	139.1	5.0	3.7	6.2	10.7	96	165
35	360	141.1	5.0	3.7	6.1	11.5	96	167
40	362	141.5	5.0	3.7	6.0	12.2	96	168
45	363	141.9	5.1	3.7	5.9	12.7	96	169
50	364	142.4	5.1	3.7	5.8	13.2	96	170

R60. South Central, Upland Hardwoods

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.2	7.8	6.0	86	15
5	0	24.4	1.1	3.8	5.1	2.4	86	37
10	16	32.4	1.8	3.6	4.1	2.4	86	44
15	31	40.3	2.3	3.4	3.8	3.0	86	53
20	47	48.1	2.7	3.3	3.8	3.8	86	62
25	64	56.6	3.2	3.1	4.1	4.4	86	71
30	80	64.5	3.6	3.0	4.5	5.0	86	81
35	98	73.3	4.0	2.9	5.0	5.5	86	91
40	116	81.8	4.3	2.9	5.5	6.0	86	101
45	135	91.5	4.7	2.8	6.1	6.4	86	111
50	156	101.4	4.9	2.7	6.8	6.8	86	123
55	176	111.0	5.0	2.7	7.4	7.2	86	133
60	195	119.9	5.1	2.6	8.0	7.5	86	143
65	213	128.6	5.0	2.6	8.6	7.8	86	153
70	230	136.5	4.9	2.5	9.1	8.1	86	161
75	247	144.4	4.7	2.5	9.6	8.4	86	170
80	262	151.6	4.5	2.5	10.1	8.6	86	177
85	279	159.1	4.2	2.5	10.6	8.9	86	185
90	292	165.2	3.9	2.4	11.0	9.1	86	192

R61. Southeast, Lowland Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.7	6.5	6.0	150	13
5	0	23.5	0.5	1.7	4.3	2.4	150	32
10	11	28.7	0.9	1.7	3.4	2.4	150	37
15	23	33.9	1.0	1.7	3.1	3.0	150	43
20	39	41.4	1.2	1.7	3.2	3.8	150	51
25	54	48.2	1.4	1.6	3.4	4.4	150	59
30	71	55.9	1.6	1.6	3.7	5.0	150	68
35	87	63.1	1.8	1.6	4.1	5.5	150	76
40	104	70.4	2.0	1.6	4.5	6.0	150	85
45	121	78.3	2.3	1.6	5.0	6.4	150	94
50	138	85.6	2.4	1.5	5.5	6.8	150	102
55	155	92.9	2.6	1.5	5.9	7.2	150	110
60	172	100.7	2.8	1.5	6.4	7.5	150	119
65	189	107.8	2.9	1.5	6.9	7.8	150	127
70	205	114.9	3.0	1.5	7.3	8.1	150	135
75	219	120.9	3.1	1.5	7.7	8.4	150	142
80	234	127.3	3.1	1.5	8.1	8.6	150	149
85	249	133.6	3.2	1.5	8.5	8.9	150	156
90	264	139.8	3.2	1.5	8.9	9.1	150	162

R62. Southeast, Natural Pine, high productivity sites (greater than 85 cu.ft./ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.3	9.0	12.2	104	23
5	0	14.4	0.4	3.8	7.1	6.5	104	32
10	20	21.9	0.5	3.6	6.3	6.4	104	39
15	47	31.9	0.7	3.4	6.0	7.5	104	49
20	76	42.4	0.9	3.2	6.0	8.7	104	61
25	108	54.2	1.1	3.1	6.3	9.8	104	75
30	140	65.8	1.3	3.0	6.8	10.7	104	88
35	173	77.5	1.5	2.9	7.4	11.5	104	101
40	205	89.1	1.6	2.9	8.1	12.2	104	114
45	238	100.6	1.8	2.8	8.8	12.7	104	127
50	268	111.1	1.9	2.8	9.5	13.2	104	138
55	297	121.5	2.0	2.7	10.2	13.7	104	150
60	327	131.8	2.1	2.7	11.0	14.1	104	162
65	356	141.9	2.1	2.7	11.7	14.4	104	173
70	379	149.7	2.2	2.6	12.3	14.7	104	182
75	402	157.7	2.2	2.6	12.9	15.0	104	190
80	423	164.9	2.2	2.6	13.4	15.2	104	198
85	444	172.0	2.3	2.6	14.0	15.5	104	206
90	462	177.9	2.3	2.6	14.5	15.7	104	213

R63. Southeast, Natural Pine, medium productivity sites (between 50 and 84 cu.ft./ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.3	7.6	12.2	105	21
5	0	14.4	0.3	3.8	6.1	6.5	105	31
10	18	21.2	0.5	3.6	5.4	6.4	105	37
15	35	27.3	0.6	3.4	5.0	7.5	105	44
20	56	35.1	0.8	3.3	5.0	8.7	105	53
25	80	43.7	0.9	3.2	5.1	9.8	105	63
30	105	52.8	1.1	3.1	5.5	10.7	105	73
35	131	62.3	1.3	3.0	6.0	11.5	105	84
40	161	73.1	1.4	3.0	6.6	12.2	105	96
45	186	82.2	1.6	2.9	7.2	12.7	105	107
50	212	91.5	1.7	2.9	7.8	13.2	105	117
55	236	100.0	1.8	2.8	8.4	13.7	105	127
60	260	108.5	1.9	2.8	9.0	14.1	105	136
65	282	116.0	1.9	2.8	9.6	14.4	105	145
70	303	123.6	2.0	2.7	10.1	14.7	105	153
75	322	130.0	2.0	2.7	10.6	15.0	105	160
80	339	136.1	2.1	2.7	11.1	15.2	105	167
85	355	141.5	2.1	2.7	11.5	15.5	105	173
90	369	146.3	2.2	2.7	11.9	15.7	105	179

R64. Southeast, Oak-Pine, high productivity sites (greater than 85 cu.ft./ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.4	6.7	10.3	82	18
5	0	14.2	0.5	3.8	5.3	5.8	82	30
10	23	25.1	0.7	3.5	4.9	5.9	82	40
15	40	33.3	1.0	3.4	4.6	6.8	82	49
20	56	41.1	1.2	3.3	4.5	7.7	82	58
25	75	49.6	1.4	3.3	4.6	8.6	82	67
30	97	59.7	1.6	3.2	4.9	9.2	82	79
35	119	69.8	1.8	3.1	5.2	9.8	82	90
40	142	79.9	1.9	3.1	5.7	10.2	82	101
45	164	90.0	2.0	3.0	6.2	10.6	82	112
50	187	99.9	2.0	3.0	6.7	11.0	82	123
55	210	109.6	2.0	3.0	7.2	11.3	82	133
60	234	119.7	1.9	2.9	7.8	11.5	82	144
65	257	129.7	1.8	2.9	8.4	11.8	82	155
70	282	139.9	1.7	2.9	9.0	12.0	82	165
75	307	149.9	1.5	2.9	9.6	12.1	82	176
80	330	159.2	1.4	2.9	10.2	12.3	82	186
85	353	168.0	1.2	2.8	10.7	12.5	82	195
90	374	176.2	1.1	2.8	11.2	12.6	82	204

R65. Southeast, Oak-Pine, medium productivity sites (between 50 and 84 cu.ft./ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.4	5.7	10.3	82	17
5	0	14.2	0.4	3.8	4.5	5.8	82	29
10	10	19.3	0.6	3.7	3.9	5.9	82	33
15	24	26.0	0.8	3.5	3.7	6.8	82	41
20	38	32.6	1.0	3.4	3.6	7.7	82	48
25	54	39.7	1.1	3.4	3.7	8.6	82	56
30	69	46.7	1.3	3.3	3.9	9.2	82	64
35	88	55.7	1.5	3.2	4.2	9.8	82	74
40	108	64.9	1.7	3.2	4.6	10.2	82	85
45	129	74.5	1.8	3.1	5.1	10.6	82	95
50	149	83.0	1.9	3.1	5.6	11.0	82	105
55	168	91.7	2.0	3.0	6.0	11.3	82	114
60	189	100.6	2.0	3.0	6.6	11.5	82	124
65	209	109.3	2.0	3.0	7.1	11.8	82	133
70	229	117.8	1.9	3.0	7.6	12.0	82	142
75	247	125.1	1.9	2.9	8.0	12.1	82	150
80	262	131.7	1.8	2.9	8.4	12.3	82	157
85	275	136.7	1.7	2.9	8.7	12.5	82	163
90	283	140.3	1.7	2.9	8.9	12.6	82	166

R66. Southeast, Planted Pine, high productivity sites (greater than 85 cu.ft./ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.8	4.7	12.2	105	19
5	0	12.4	0.4	4.0	3.7	6.5	105	27
10	48	30.8	0.4	3.8	3.6	6.4	105	45
15	147	67.4	0.9	3.7	4.4	7.5	105	84
20	245	101.9	1.3	3.7	5.2	8.7	105	121
25	315	125.6	1.6	3.7	5.8	9.8	105	146
30	347	136.1	1.8	3.7	5.9	10.7	105	158
35	352	137.5	1.8	3.6	5.8	11.5	105	160
40	355	138.6	1.8	3.6	5.6	12.2	105	162
45	359	139.7	1.8	3.6	5.6	12.7	105	164
50	362	140.9	1.8	3.6	5.5	13.2	105	165

R67. Southeast, Planted Pine, high productivity sites (greater than 85 cu.ft./ac/yr), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.8	5.8	12.2	105	20
5	0	12.4	0.6	4.0	4.5	6.5	105	28
10	78	42.2	0.6	3.8	4.7	6.4	105	58
15	227	95.8	1.3	3.7	5.9	7.5	105	114
20	350	136.9	1.8	3.6	6.9	8.7	105	158
25	429	162.1	2.1	3.6	7.4	9.8	105	185
30	462	172.1	2.3	3.6	7.5	10.7	105	196
35	464	172.8	2.3	3.6	7.2	11.5	105	197
40	466	173.4	2.3	3.6	7.1	12.2	105	199
45	468	174.1	2.3	3.6	7.0	12.7	105	200
50	470	174.7	2.3	3.6	6.9	13.2	105	201

R68. Southeast, Planted Pine, medium productivity sites (between 50 and 84 cu.ft./ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.8	3.8	12.2	109	18
5	0	12.4	0.3	4.0	3.0	6.5	109	26
10	28	23.1	0.3	3.9	2.8	6.4	109	36
15	95	48.4	0.6	3.8	3.2	7.5	109	64
20	165	73.9	1.0	3.7	3.9	8.7	109	91
25	219	93.2	1.2	3.7	4.3	9.8	109	112
30	252	104.5	1.4	3.7	4.5	10.7	109	125
35	260	107.3	1.4	3.7	4.5	11.5	109	128
40	263	108.1	1.4	3.7	4.4	12.2	109	130
45	265	108.9	1.4	3.7	4.3	12.7	109	131
50	268	109.8	1.4	3.7	4.3	13.2	109	132

R69. Southeast, Planted Pine, medium productivity sites (between 50 and 84 cu.ft./ac/yr), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.8	4.8	12.2	109	19
5	0	12.4	0.5	4.0	3.7	6.5	109	27
10	45	29.7	0.4	3.9	3.6	6.4	109	44
15	152	69.3	0.9	3.7	4.5	7.5	109	86
20	255	105.4	1.4	3.7	5.4	8.7	109	125
25	321	127.5	1.7	3.7	5.8	9.8	109	148
30	354	138.2	1.8	3.6	6.0	10.7	109	160
35	360	140.3	1.8	3.6	5.9	11.5	109	163
40	362	140.8	1.8	3.6	5.7	12.2	109	164
45	363	141.2	1.9	3.6	5.6	12.7	109	165
50	364	141.7	1.9	3.6	5.6	13.2	109	166

R70. Southeast, Upland Hardwoods

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	1.3	6.6	6.0	86	14
5	0	21.5	0.6	3.7	4.3	2.4	86	33
10	16	29.6	1.0	3.5	3.5	2.4	86	40
15	31	37.6	1.2	3.4	3.2	3.0	86	48
20	47	45.6	1.4	3.2	3.3	3.8	86	57
25	64	54.1	1.7	3.1	3.5	4.4	86	67
30	80	62.0	1.9	3.1	3.9	5.0	86	76
35	98	70.9	2.0	3.0	4.3	5.5	86	86
40	116	79.4	2.2	2.9	4.8	6.0	86	95
45	135	89.1	2.3	2.8	5.3	6.4	86	106
50	156	99.0	2.4	2.8	5.9	6.8	86	117
55	176	108.7	2.4	2.7	6.5	7.2	86	127
60	195	117.5	2.3	2.7	7.0	7.5	86	137
65	213	126.2	2.2	2.7	7.5	7.8	86	146
70	230	134.1	2.1	2.6	8.0	8.1	86	155
75	247	141.9	2.0	2.6	8.4	8.4	86	163
80	262	149.0	1.9	2.6	8.9	8.6	86	171
85	279	156.4	1.7	2.6	9.3	8.9	86	179
90	292	162.5	1.6	2.5	9.7	9.1	86	185

Chapter 1, GHG Inventories: Part I
Appendix Section 1: Tables A1-A55
Afforestation, or establishment on nonforest land, tables.

List of Tables

A39. Rocky Mountain, North, Fir & Spruce
A40. Rocky Mountain, North, Lodgepole Pine
A41. Rocky Mountain, North, Ponderosa Pine
A42. Rocky Mountain, South, Douglas-fir
A43. Rocky Mountain, South, Fir & Spruce
A44. Rocky Mountain, South, Lodgepole Pine
A45. Rocky Mountain, South, Ponderosa Pine
A46. South Central, Lowland Hardwood
A47. South Central, Natural Pine, high productivity sites (growth rate greater than 120 cubic feet wood per acre per year)
A48. South Central, Natural Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year)
A49. South Central, Oak-Pine, high productivity sites (growth rate greater than 120 cubic feet wood per acre per year)
A50. South Central, Oak-Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year)
A51. South Central, Planted Pine, high productivity sites (growth rate greater than 120 cubic feet wood per acre per year), lower intensity management
A52. South Central, Planted Pine, high productivity sites (growth rate greater than 120 cubic feet wood per acre per year), higher intensity management
A53. South Central, Planted Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year), lower intensity management
A54. South Central, Planted Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year), higher intensity management
A55. South Central, Upland Hardwoods
A56. Southeast, Lowland Hardwood
A57. Southeast, Natural Pine, high productivity sites (growth rate greater than 85 cubic feet wood per acre per year)
A58. Southeast, Natural Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year)
A59. Southeast, Oak-Pine, high productivity sites (growth rate greater than 85 cubic feet wood per acre per year)
A60. Southeast, Oak-Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year)
A61. Southeast, Planted Pine, high productivity sites (growth rate greater than 85 cubic feet wood per acre per year), lower intensity management
A62. Southeast, Planted Pine, high productivity sites (growth rate greater than 85 cubic feet wood per acre per year), higher intensity management
A63. Southeast, Planted Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year), lower intensity management
A64. Southeast, Planted Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year), higher intensity management
A65. Southeast, Upland Hardwoods

A1. Northeast, Aspen & Birch

Age	Mean Volume	Mean Carbon Density

		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	178	0
5	0	16.0	0.0	2.2	0.0	1.6	178	20
15	13	22.5	0.9	2.1	1.2	4.0	198	31
25	34	32.9	1.8	2.1	2.3	5.8	218	45
35	58	45.0	2.6	2.1	3.4	7.3	227	60
45	85	57.7	3.4	2.1	4.4	8.4	231	76
55	112	70.8	4.1	2.1	5.5	9.3	233	92
65	142	84.4	4.8	2.0	6.5	10.1	233	108
75	173	98.3	5.3	2.0	7.6	10.7	234	124
85	205	112.7	5.9	2.0	8.8	11.3	234	141
95	239	127.4	6.3	2.0	9.9	11.8	234	157
105	274	142.4	6.7	2.0	11.1	12.2	234	174
115	311	157.6	7.1	2.0	12.3	12.5	234	191
125	350	173.1	7.3	2.0	13.5	12.9	234	209
135	390	188.7	7.5	2.0	14.7	13.2	234	226
145	432	204.5	7.7	2.0	15.9	13.4	234	243
155	475	220.3	7.8	2.0	17.1	13.7	234	261
165	520	236.3	7.8	2.0	18.4	13.9	234	278
175	566	252.2	7.8	2.0	19.6	14.1	234	296

A2. Northeast, Elm, Ash, Red Maple

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	101	0
5	0	22.1	0.0	1.9	0.0	4.2	101	28
15	31	38.2	1.6	1.8	2.0	10.8	112	55
25	62	54.4	3.0	1.8	3.6	15.8	123	79
35	97	72.7	4.3	1.7	5.0	19.7	129	103
45	133	90.7	5.5	1.7	6.4	22.7	131	127
55	166	107.2	6.3	1.7	7.6	25.3	132	148
65	196	122.4	6.9	1.7	8.7	27.4	132	167
75	225	136.1	7.2	1.7	9.6	29.1	132	184
85	251	148.6	7.2	1.6	10.5	30.7	133	199
95	274	159.9	7.0	1.6	11.3	32.0	133	212
105	296	169.9	6.6	1.6	12.0	33.1	133	223
115	314	178.7	6.2	1.6	12.7	34.2	133	233
125	331	186.4	5.7	1.6	13.2	35.1	133	242
135	345	192.9	5.3	1.6	13.7	35.9	133	249
145	357	198.3	4.9	1.6	14.0	36.6	133	255
155	367	202.6	4.5	1.6	14.3	37.3	133	260
165	374	205.9	4.3	1.6	14.6	37.9	133	264
175	378	208.0	4.1	1.6	14.7	38.4	133	267

A3. Northeast, Maple, Beech, Birch

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	105	0
5	0	22.1	0.0	1.9	0.0	4.2	105	28
15	28	36.9	1.5	1.8	1.9	10.8	117	53
25	58	52.6	2.9	1.8	3.4	15.8	128	77
35	90	68.9	4.1	1.7	4.7	19.7	134	99
45	119	83.9	5.1	1.7	5.9	22.7	136	119
55	147	97.7	5.9	1.7	6.9	25.3	137	138
65	172	110.4	6.5	1.7	7.8	27.4	137	154
75	196	122.0	6.9	1.7	8.6	29.1	138	168
85	217	132.5	7.2	1.7	9.4	30.7	138	181
95	237	141.9	7.2	1.7	10.0	32.0	138	193
105	254	150.3	7.2	1.6	10.6	33.1	138	203
115	270	157.7	7.1	1.6	11.2	34.2	138	212
125	283	164.1	6.9	1.6	11.6	35.1	138	219
135	295	169.4	6.7	1.6	12.0	35.9	138	226
145	304	173.9	6.5	1.6	12.3	36.6	138	231
155	312	177.4	6.3	1.6	12.6	37.3	138	235
165	317	180.0	6.1	1.6	12.7	37.9	138	238
175	321	181.6	6.0	1.6	12.9	38.4	138	241

A4. Northeast, Oak & Hickory

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	64	0
5	0	22.2	0.0	2.0	0.0	0.9	64	25
15	55	52.0	2.2	1.9	2.9	2.5	71	62
25	96	74.1	3.5	1.8	4.8	3.9	78	88
35	135	94.8	4.4	1.8	6.4	5.2	81	113
45	173	114.4	4.9	1.8	7.8	6.3	83	135
55	210	132.7	5.0	1.8	9.1	7.2	83	156
65	244	149.9	4.9	1.8	10.2	8.1	84	175
75	277	166.0	4.6	1.8	11.4	8.9	84	193
85	309	181.1	4.2	1.8	12.4	9.7	84	209
95	339	195.3	3.8	1.8	13.4	10.3	84	224
105	367	208.4	3.3	1.8	14.3	10.9	84	239
115	394	220.6	2.8	1.7	15.1	11.5	84	252
125	419	232.0	2.4	1.7	15.9	12.0	84	264
135	442	242.4	2.1	1.7	16.6	12.5	84	275
145	464	252.1	1.8	1.7	17.2	12.9	84	286
155	484	260.9	1.5	1.7	17.8	13.3	84	295
165	502	268.9	1.3	1.7	18.4	13.7	84	304
175	519	276.2	1.1	1.7	18.9	14.1	84	312

A5. Northeast, Spruce & Balsam Fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	145	0
5	0	19.3	0.0	1.6	0.0	5.0	145	26
15	11	24.3	1.5	1.5	1.2	13.0	161	42
25	29	31.9	2.9	1.5	2.4	19.0	177	58
35	52	41.5	4.4	1.5	3.5	23.7	185	75
45	77	52.0	5.7	1.4	4.6	27.5	188	91
55	103	62.6	6.8	1.4	5.7	30.7	189	107
65	126	72.2	7.6	1.4	6.6	33.3	190	121
75	149	81.3	8.1	1.3	7.5	35.5	190	134
85	171	89.9	8.5	1.3	8.3	37.4	190	145
95	192	97.9	8.7	1.3	9.0	39.1	191	156
105	211	105.4	8.8	1.3	9.7	40.6	191	166
115	230	112.3	8.8	1.3	10.4	41.9	191	175
125	247	118.9	8.7	1.3	11.0	43.0	191	183
135	264	125.0	8.5	1.3	11.5	44.0	191	190
145	279	130.7	8.4	1.3	12.1	45.0	191	197
155	294	136.0	8.2	1.3	12.5	45.8	191	204
165	310	142.0	7.9	1.3	13.1	46.6	191	211
175	326	147.7	7.6	1.2	13.6	47.3	191	217

A6. Northeast, White, Red & Jack Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	147	0
5	0	19.9	0.0	1.9	0.0	3.1	148	25
15	30	33.1	0.9	1.8	1.2	7.1	164	44
25	54	43.6	1.6	1.8	2.0	9.4	180	58
35	78	53.6	2.2	1.7	2.7	11.0	188	71
45	101	63.1	2.7	1.7	3.4	12.2	191	83
55	123	72.2	3.2	1.7	3.9	13.0	193	94
65	142	80.2	3.6	1.6	4.4	13.7	193	104
75	161	87.7	3.9	1.6	4.8	14.2	194	112
85	178	94.7	4.2	1.6	5.2	14.7	194	120
95	195	101.1	4.5	1.6	5.6	15.0	194	128
105	210	107.1	4.7	1.6	5.9	15.4	194	135
115	224	112.5	4.9	1.6	6.2	15.6	194	141
125	237	117.5	5.1	1.6	6.5	15.9	194	146
135	249	122.1	5.2	1.6	6.7	16.1	194	152
145	260	126.2	5.3	1.6	7.0	16.2	194	156
155	270	130.0	5.3	1.5	7.2	16.4	194	160
165	282	134.3	5.4	1.5	7.4	16.5	194	165
175	293	138.5	5.4	1.5	7.6	16.7	194	170

A7. Northern Lake States, Aspen & Birch

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	178	0
5	0	13.9	0.0	2.1	0.0	1.6	178	17
15	76	51.2	4.2	2.0	3.7	4.0	198	65
25	150	85.6	7.4	2.0	6.7	5.8	218	107
35	208	110.8	8.4	2.0	8.9	7.3	227	137
45	231	120.5	8.3	2.0	9.7	8.4	231	149
55	240	124.3	8.1	2.0	10.0	9.3	233	154
65	243	125.8	8.1	2.0	10.2	10.1	233	156
75	245	126.4	8.1	2.0	10.2	10.7	234	157
85	246	126.7	8.0	2.0	10.2	11.3	234	158

A8. Northern Lake States, Jack Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	147	0
5	0	12.8	0.0	2.0	0.0	3.1	148	18
15	37	27.3	1.1	2.0	1.4	7.1	164	39
25	82	44.3	2.2	2.0	2.9	9.4	180	61
35	120	58.5	3.0	2.0	4.0	11.0	188	79
45	146	68.2	3.5	2.0	4.8	12.2	191	91
55	163	74.2	3.7	2.0	5.3	13.0	193	98
65	172	77.7	3.8	2.0	5.6	13.7	193	103
75	178	79.7	3.9	2.0	5.7	14.2	194	106
85	181	80.8	3.9	2.0	5.8	14.7	194	107
95	183	81.5	4.0	2.0	5.9	15.0	194	108
105	184	81.8	4.0	2.0	5.9	15.4	194	109

A9. Northern Lake States, Lowland Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	89	0
5	0	14.7	0.0	1.9	0.0	4.2	89	21
15	63	49.4	4.0	1.9	2.6	10.8	99	69
25	119	80.1	6.4	1.9	4.8	15.8	108	109
35	162	103.8	7.5	1.9	6.3	19.7	113	139
45	199	123.9	8.1	1.9	7.6	22.7	115	164
55	230	140.2	8.2	1.9	8.6	25.3	116	184
65	254	153.4	8.3	1.9	9.4	27.4	116	200
75	271	162.4	8.2	1.9	10.0	29.1	117	212
85	282	168.5	8.1	1.9	10.3	30.7	117	220
95	286	170.7	8.1	1.9	10.5	32.0	117	223
105	350	204.7	7.4	1.9	12.6	33.1	117	260

A10. Northern Lake States, Maple & Beech

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	105	0
5	0	15.0	0.0	1.7	0.0	4.2	105	21
15	1	15.8	0.5	1.7	0.7	10.8	117	30
25	10	21.4	1.2	1.6	1.4	15.8	128	41
35	34	36.3	2.5	1.5	2.7	19.7	134	63
45	73	59.3	4.1	1.5	4.5	22.7	136	92
55	118	85.2	5.5	1.4	6.4	25.3	137	124
65	162	109.4	6.2	1.4	8.3	27.4	137	153
75	200	129.7	6.5	1.3	9.8	29.1	138	176
85	230	145.4	6.5	1.3	11.0	30.7	138	195
95	253	157.2	6.4	1.3	11.9	32.0	138	209
105	271	165.7	6.2	1.3	12.6	33.1	138	219
115	283	171.8	6.1	1.3	13.0	34.2	138	226
125	292	176.1	6.0	1.3	13.3	35.1	138	232
135	298	179.0	5.9	1.3	13.6	35.9	138	236
145	302	181.1	5.8	1.3	13.7	36.6	138	239
155	306	182.6	5.8	1.3	13.8	37.3	138	241
165	308	183.6	5.8	1.3	13.9	37.9	138	242
175	309	184.2	5.7	1.3	14.0	38.4	138	244

A11. Northern Lake States, Oak & Hickory

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	64	0
5	0	21.8	0.0	2.0	0.0	0.9	64	25
15	66	64.1	3.5	1.8	4.2	2.5	71	76
25	106	88.8	5.0	1.7	6.5	3.9	78	106
35	145	112.2	5.7	1.7	8.5	5.2	81	133
45	182	133.7	5.7	1.7	10.3	6.3	83	158
55	216	153.2	5.4	1.7	11.8	7.2	83	179
65	248	170.5	4.8	1.6	13.2	8.1	84	198
75	276	186.0	4.2	1.6	14.4	8.9	84	215
85	302	199.6	3.6	1.6	15.4	9.7	84	230
95	326	211.7	3.0	1.6	16.4	10.3	84	243
105	347	222.3	2.6	1.6	17.2	10.9	84	255
115	365	231.6	2.2	1.6	17.9	11.5	84	265
125	382	239.8	1.9	1.6	18.5	12.0	84	274
135	396	247.1	1.7	1.6	19.1	12.5	84	282
145	409	253.4	1.5	1.6	19.6	12.9	84	289
155	421	258.9	1.3	1.6	20.0	13.3	84	295
165	431	263.8	1.2	1.6	20.4	13.7	84	301
175	440	268.1	1.0	1.6	20.7	14.1	84	306

A12. Northern Lake States, Red Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	147	0
5	0	12.8	0.0	2.0	0.0	3.1	148	18
15	115	56.6	2.6	2.0	3.5	7.1	164	72
25	232	98.9	3.9	2.0	6.8	9.4	180	121
35	356	141.5	3.0	2.0	10.0	11.0	188	167
45	480	182.0	3.0	2.0	13.0	12.2	191	210
55	600	218.7	3.0	1.9	15.7	13.0	193	250
65	708	250.5	3.0	1.9	18.0	13.7	193	284
75	802	276.8	3.0	1.9	19.9	14.2	194	313
85	878	297.1	3.0	1.9	21.4	14.7	194	335
95	932	311.4	3.0	1.9	22.4	15.0	194	351

A13. Northern Lake States, Spruce & Balsam Fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	145	0
5	0	14.0	0.0	2.3	0.0	5.0	145	21
15	47	36.4	2.0	1.7	2.5	13.0	161	55
25	83	53.1	3.4	1.5	4.2	19.0	177	81
35	114	66.6	4.5	1.4	5.5	23.7	185	102
45	141	78.7	5.5	1.3	6.7	27.5	188	120
55	157	85.5	6.1	1.3	7.3	30.7	189	131
65	173	92.2	6.6	1.2	7.9	33.3	190	141
75	186	97.8	7.0	1.2	8.4	35.5	190	150
85	206	105.9	7.6	1.2	9.1	37.4	190	161
95	212	108.4	7.8	1.2	9.4	39.1	191	166
105	220	111.5	8.0	1.2	9.6	40.6	191	171
115	225	113.6	8.2	1.2	9.8	41.9	191	175
125	219	111.4	8.0	1.2	9.6	43.0	191	173
135	223	113.0	8.1	1.2	9.8	44.0	191	176
145	241	120.3	8.6	1.1	10.4	45.0	191	185
155	243	121.0	8.7	1.1	10.5	45.8	191	187

A14. Northern Lake States, White Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	147	0
5	0	12.8	0.0	2.0	0.0	3.1	148	18
15	70	39.8	1.8	2.0	2.3	7.1	164	53
25	168	76.0	3.5	2.0	5.2	9.4	180	96
35	283	116.8	3.8	2.0	8.2	11.0	188	142
45	398	155.5	2.4	2.0	11.1	12.2	191	183
55	503	189.0	2.4	1.9	13.6	13.0	193	219
65	592	216.5	2.4	1.9	15.6	13.7	193	248
75	666	238.3	2.4	1.9	17.1	14.2	194	272
85	725	255.3	2.4	1.9	18.4	14.7	194	290
95	772	268.3	2.4	1.9	19.3	15.0	194	305
105	808	278.2	2.4	1.9	20.0	15.4	194	316
115	835	285.8	2.4	1.9	20.6	15.6	194	324
125	856	291.5	2.4	1.9	21.0	15.9	194	330
135	873	295.8	2.4	1.9	21.3	16.1	194	335
145	885	299.0	2.4	1.9	21.5	16.2	194	339
155	894	301.4	2.4	1.9	21.7	16.4	194	341
165	901	303.2	2.4	1.9	21.8	16.5	194	344
175	906	304.6	2.4	1.9	21.9	16.7	194	345

A15. Northern Prairie States, Lowland Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	94	0
5	0	33.3	0.0	2.1	0.0	4.2	95	40
15	33	49.1	2.4	2.0	2.4	10.8	105	67
25	46	55.8	3.6	1.9	3.4	15.8	116	80
35	59	61.7	4.4	1.9	4.1	19.7	121	92
45	70	67.0	4.9	1.9	4.6	22.7	123	101
55	80	71.8	5.3	1.8	4.9	25.3	124	109
65	89	76.0	5.6	1.8	5.3	27.4	124	116
75	96	79.9	5.8	1.8	5.5	29.1	124	122
85	104	83.3	5.9	1.8	5.8	30.7	124	127
95	110	86.3	6.1	1.8	6.0	32.0	124	132
105	116	89.0	6.2	1.8	6.2	33.1	124	136
115	121	91.5	6.3	1.8	6.3	34.2	124	140
125	125	93.7	6.3	1.8	6.5	35.1	124	143
135	130	95.6	6.4	1.8	6.6	35.9	124	146
145	133	97.4	6.4	1.7	6.7	36.6	124	149
155	136	98.9	6.5	1.7	6.9	37.3	124	151
165	137	99.1	6.5	1.7	6.9	37.9	124	152

A16. Northern Prairie States, Maple & Beech

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	105	0
5	0	24.2	0.0	1.6	0.0	4.2	105	30
15	37	44.1	1.9	1.4	2.1	10.8	117	60
25	53	52.7	2.7	1.4	3.1	15.8	128	76
35	68	60.6	3.3	1.4	3.7	19.7	134	89
45	82	67.8	3.7	1.3	4.2	22.7	136	100
55	94	74.3	4.0	1.3	4.7	25.3	137	110
65	106	80.3	4.2	1.3	5.1	27.4	137	118
75	117	85.8	4.4	1.3	5.4	29.1	138	126
85	127	90.8	4.5	1.2	5.8	30.7	138	133
95	136	95.4	4.6	1.2	6.1	32.0	138	139
105	145	99.6	4.7	1.2	6.3	33.1	138	145
115	152	103.5	4.7	1.2	6.6	34.2	138	150
125	160	107.0	4.7	1.2	6.8	35.1	138	155
135	166	110.3	4.8	1.2	7.0	35.9	138	159
145	173	113.2	4.8	1.2	7.2	36.6	138	163
155	178	116.0	4.8	1.2	7.4	37.3	138	167
165	184	118.5	4.8	1.2	7.5	37.9	138	170
175	188	120.8	4.8	1.2	7.7	38.4	138	173

A17. Northern Prairie States, Oak & Hickory

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	64	0
5	0	28.6	0.0	2.0	0.0	0.9	64	31
15	57	63.0	2.4	1.8	3.4	2.5	71	73
25	90	83.0	3.6	1.7	5.2	3.9	78	97
35	123	102.5	4.3	1.6	6.8	5.2	81	120
45	154	121.0	4.8	1.6	8.1	6.3	83	142
55	183	138.4	5.0	1.6	9.3	7.2	83	162
65	211	154.5	5.1	1.6	10.4	8.1	84	180
75	236	169.4	5.1	1.5	11.4	8.9	84	196
85	260	183.1	5.0	1.5	12.4	9.7	84	212
95	281	195.6	4.9	1.5	13.2	10.3	84	225
105	301	207.0	4.7	1.5	14.0	10.9	84	238
115	319	217.4	4.5	1.5	14.7	11.5	84	250
125	336	226.9	4.4	1.5	15.3	12.0	84	260
135	351	235.4	4.2	1.5	15.9	12.5	84	270
145	365	243.2	4.0	1.5	16.4	12.9	84	278
155	377	250.3	3.9	1.5	16.9	13.3	84	286
165	388	256.7	3.8	1.5	17.3	13.7	84	293
175	399	262.5	3.6	1.4	17.7	14.1	84	299

A18. Northern Prairie States, Pines

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	79	0
5	0	11.7	0.0	2.1	0.0	3.1	80	17
15	27	24.1	-0.9	1.8	1.3	7.1	88	33
25	41	30.2	0.3	1.7	1.9	9.4	97	44
35	54	36.2	1.2	1.7	2.5	11.0	101	52
45	68	42.0	1.8	1.6	3.0	12.2	103	61
55	81	47.8	2.3	1.6	3.4	13.0	104	68
65	94	53.6	2.7	1.5	3.9	13.7	104	75
75	107	59.2	3.0	1.5	4.3	14.2	104	82
85	121	64.8	3.3	1.5	4.7	14.7	104	89
95	134	70.2	3.5	1.5	5.1	15.0	104	95
105	147	75.6	3.8	1.4	5.5	15.4	105	102
115	160	81.0	4.0	1.4	5.9	15.6	105	108
125	173	86.3	4.2	1.4	6.3	15.9	105	114
135	186	91.4	4.3	1.4	6.7	16.1	105	120
145	198	96.6	4.5	1.4	7.0	16.2	105	126
155	211	101.6	4.7	1.4	7.4	16.4	105	131
165	224	106.6	4.8	1.4	7.8	16.5	105	137
175	236	111.5	5.0	1.3	8.1	16.7	105	143

A19. Pacific Southwest, Douglas-fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	69	0
5	0	22.3	0.0	4.3	0.0	5.2	70	32
15	38	36.3	0.3	3.9	1.8	13.0	77	55
25	117	64.6	0.7	3.5	4.8	18.6	85	92
35	234	105.9	1.3	3.1	8.9	22.9	89	142
45	362	149.7	1.9	2.9	13.1	26.2	90	194
55	488	191.7	2.5	2.8	17.1	28.9	91	243
65	588	224.2	3.0	2.7	20.2	31.1	91	281
75	657	246.3	3.3	2.7	22.3	33.0	91	307
85	711	263.3	3.5	2.6	23.9	34.5	91	328
95	755	277.1	3.7	2.6	25.2	35.9	91	344
105	796	289.8	3.9	2.6	26.4	37.0	91	360
115	836	302.0	4.1	2.6	27.5	38.0	91	374
125	875	313.7	4.2	2.5	28.6	39.0	91	388
135	912	324.9	4.4	2.5	29.6	39.8	91	401
145	947	335.5	4.5	2.5	30.6	40.5	91	414
155	982	345.7	4.7	2.5	31.5	41.1	91	426
165	1015	355.3	4.8	2.5	32.4	41.7	91	437
175	1046	364.6	4.9	2.5	33.3	42.3	91	448

A20. Pacific Southwest, Mixed Conifer

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	52	0
5	0	40.1	0.0	3.1	0.0	5.2	52	48
15	42	55.5	2.2	2.4	2.6	13.0	58	76
25	63	63.1	3.5	2.2	4.2	18.6	64	92
35	105	78.0	5.4	1.8	6.2	22.9	66	114
45	165	99.0	7.8	1.5	8.8	26.2	68	143
55	227	120.0	10.1	1.3	11.2	28.9	68	172
65	289	140.2	12.3	1.2	13.4	31.1	68	198
75	351	159.9	14.4	1.1	15.6	33.0	68	224
85	409	177.9	16.2	1.0	17.5	34.5	69	247
95	464	194.4	17.9	1.0	19.2	35.9	69	268
105	502	205.8	19.1	1.0	20.5	37.0	69	283
115	536	215.7	20.1	1.1	21.5	38.0	69	296
125	564	223.7	21.0	1.1	22.3	39.0	69	307
135	588	230.3	21.7	1.2	23.0	39.8	69	316
145	611	236.8	22.3	1.2	23.7	40.5	69	324
155	635	243.3	23.0	1.2	24.4	41.1	69	333
165	658	249.7	23.6	1.2	25.0	41.7	69	341
175	679	255.3	24.2	1.3	25.6	42.3	69	349

A21. Pacific Southwest, Ponderosa Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	63	0
5	0	40.1	0.0	3.1	0.0	5.2	63	48
15	16	45.9	1.3	2.8	1.7	13.0	70	65
25	38	54.2	2.7	2.5	3.3	18.6	77	81
35	79	68.7	4.6	2.0	5.3	22.9	81	104
45	128	86.0	6.6	1.7	7.5	26.2	82	128
55	180	104.0	8.6	1.5	9.6	28.9	83	153
65	231	121.2	10.5	1.3	11.5	31.1	83	176
75	280	137.4	12.2	1.2	13.3	33.0	83	197
85	327	152.5	13.8	1.1	15.0	34.5	83	217
95	372	166.6	15.3	1.0	16.5	35.9	83	235
105	414	179.5	16.6	1.0	17.8	37.0	83	252
115	453	191.2	17.8	1.0	19.0	38.0	83	267
125	488	201.7	18.9	1.0	20.1	39.0	83	281
135	520	211.0	19.8	1.1	21.1	39.8	83	293
145	549	219.1	20.6	1.1	21.9	40.5	83	303
155	573	226.1	21.3	1.1	22.6	41.1	83	312
165	593	231.8	21.9	1.2	23.2	41.7	83	320
175	609	236.3	22.4	1.2	23.7	42.3	83	326

A22. Pacific Southwest, Redwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	64	0
5	0	34.4	0.0	4.1	0.0	8.1	65	47
15	84	60.3	0.4	3.4	3.8	20.7	72	89
25	169	86.0	0.9	3.1	7.3	30.0	79	127
35	292	122.2	1.4	2.8	11.8	37.2	82	175
45	432	161.6	2.0	2.5	16.4	42.9	84	225
55	581	202.3	2.6	2.4	21.1	47.6	84	276
65	708	235.5	3.1	2.2	24.9	51.4	85	317
75	834	267.4	3.5	2.2	28.5	54.6	85	356
85	920	288.8	3.8	2.1	31.0	57.4	85	383
95	991	305.9	4.1	2.1	32.9	59.8	85	405
105	1058	321.6	4.3	2.0	34.7	61.9	85	425
115	1122	336.7	4.5	2.0	36.3	63.7	85	443
125	1185	351.1	4.7	2.0	37.9	65.4	85	461
135	1247	364.9	4.9	2.0	39.5	66.8	85	478
145	1306	378.0	5.1	1.9	40.9	68.1	85	494
155	1362	390.2	5.3	2.0	42.2	69.3	85	509
165	1415	401.5	5.4	2.0	43.5	70.4	85	523
175	1464	411.9	5.6	2.1	44.6	71.4	85	535

A23. Pacific Southwest, True Fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	103	0
5	0	24.3	0.0	3.1	0.0	5.2	104	33
15	10	28.9	1.9	3.0	1.2	13.0	115	48
25	33	38.7	4.6	2.7	2.8	18.6	126	67
35	59	49.9	7.4	2.5	4.4	22.9	132	87
45	91	63.1	10.6	2.4	6.1	26.2	134	108
55	133	80.4	14.4	2.2	8.2	28.9	135	134
65	197	106.3	19.9	2.1	11.1	31.1	136	171
75	278	137.4	26.4	1.9	14.6	33.0	136	213
85	359	167.7	32.6	1.8	18.0	34.5	136	255
95	435	194.9	38.2	1.8	21.0	35.9	136	292
105	502	217.8	42.9	1.7	23.6	37.0	136	323
115	561	237.7	47.0	1.7	25.7	38.0	136	350
125	614	254.7	50.4	1.6	27.6	39.0	136	373
135	659	269.1	53.4	1.6	29.2	39.8	136	393
145	698	281.1	55.8	1.6	30.5	40.5	136	409
155	729	290.7	57.8	1.6	31.6	41.1	136	423
165	754	298.0	59.3	1.6	32.4	41.7	136	433
175	771	303.2	60.3	1.6	32.9	42.3	136	440

A24. Pacific Northwest, Eastside, Douglas-fir & Larch

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	66	0
5	52	41.4	0.3	3.7	2.0	5.2	66	52
15	63	45.2	0.4	3.7	3.0	13.0	74	65
25	91	55.2	0.6	3.6	4.4	18.6	81	82
35	143	74.0	0.8	3.6	6.7	22.9	85	108
45	203	94.9	1.2	3.5	9.1	26.2	86	135
55	266	116.8	1.5	3.5	11.5	28.9	87	162
65	325	137.3	1.8	3.4	13.7	31.1	87	187
75	374	153.9	2.0	3.4	15.5	33.0	87	208
85	420	169.1	2.2	3.4	17.1	34.5	87	226
95	455	180.8	2.4	3.4	18.4	35.9	87	241
105	476	187.7	2.5	3.4	19.1	37.0	87	250
115	491	192.8	2.6	3.4	19.7	38.0	87	256
125	504	196.9	2.6	3.3	20.1	39.0	87	262
135	516	201.0	2.7	3.3	20.6	39.8	87	267
145	527	204.5	2.8	3.3	20.9	40.5	87	272
155	539	208.3	2.8	3.3	21.3	41.1	87	277
165	549	211.8	2.9	3.3	21.7	41.7	87	281
175	560	215.2	2.9	3.3	22.0	42.3	87	286

A25. Pacific Northwest, Eastside, Lodgepole Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	47	0
5	17	20.2	0.5	2.8	0.5	2.4	48	26
15	24	22.4	1.0	2.7	1.1	6.4	53	34
25	42	27.9	1.8	2.5	1.9	9.8	58	44
35	92	43.1	3.4	2.3	3.5	12.6	61	65
45	161	63.5	5.5	2.1	5.5	14.9	62	91
55	204	75.8	6.7	2.0	6.8	17.0	62	108
65	235	84.3	7.6	1.9	7.6	18.7	62	120
75	264	92.1	8.5	1.9	8.4	20.3	62	131
85	285	97.8	9.0	1.8	9.0	21.7	62	139
95	302	102.4	9.5	1.8	9.5	22.9	62	146
105	316	106.0	9.9	1.8	9.8	24.0	62	152
115	329	109.2	10.3	1.8	10.1	25.0	62	156
125	337	111.5	10.5	1.8	10.3	25.8	62	160
135	344	113.3	10.7	1.8	10.5	26.7	62	163
145	351	115.0	10.9	1.8	10.7	27.4	62	166
155	358	116.8	11.0	1.8	10.9	28.1	62	169
165	365	118.6	11.2	1.8	11.0	28.7	62	171
175	372	120.4	11.4	1.8	11.2	29.3	62	174

A26. Pacific Northwest, Eastside, Ponderosa Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	53	0
5	17	20.2	0.5	3.1	0.6	2.4	53	27
15	34	25.4	1.3	2.9	1.5	6.4	59	38
25	56	32.2	2.2	2.8	2.5	9.8	65	49
35	84	40.8	3.2	2.7	3.6	12.6	67	63
45	119	51.2	4.3	2.5	4.9	14.9	69	78
55	150	60.5	5.3	2.4	5.9	17.0	69	91
65	175	67.6	6.0	2.4	6.7	18.7	69	102
75	196	73.5	6.7	2.3	7.4	20.3	70	110
85	214	78.6	7.2	2.3	8.0	21.7	70	118
95	230	83.0	7.7	2.3	8.5	22.9	70	124
105	246	87.3	8.1	2.3	8.9	24.0	70	131
115	262	91.5	8.6	2.2	9.4	25.0	70	137
125	277	95.7	9.0	2.2	9.9	25.8	70	143
135	293	99.9	9.4	2.2	10.3	26.7	70	148
145	309	104.0	9.8	2.2	10.7	27.4	70	154
155	324	108.1	10.2	2.2	11.1	28.1	70	160
165	340	112.1	10.6	2.1	11.6	28.7	70	165
175	356	116.1	11.0	2.1	12.0	29.3	70	171

A27. Pacific Northwest, Eastside, True Fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	107	0
5	24	34.5	2.0	2.8	1.1	5.2	107	46
15	35	39.4	4.0	2.7	2.3	13.0	119	61
25	44	43.3	5.5	2.7	3.2	18.6	130	73
35	70	54.3	8.3	2.6	4.8	22.9	136	93
45	108	70.4	12.0	2.5	6.7	26.2	139	118
55	154	89.0	16.1	2.4	8.9	28.9	140	145
65	196	105.7	19.8	2.4	10.8	31.1	140	170
75	231	119.4	22.8	2.3	12.4	33.0	140	190
85	259	130.2	25.1	2.3	13.6	34.5	140	206
95	281	138.5	26.9	2.3	14.6	35.9	140	218
105	298	145.1	28.4	2.2	15.3	37.0	140	228
115	313	150.6	29.6	2.2	15.9	38.0	140	236
125	327	156.0	30.8	2.2	16.5	39.0	140	245
135	342	161.5	31.9	2.2	17.1	39.8	140	252
145	357	166.8	33.0	2.2	17.7	40.5	140	260
155	372	172.2	34.2	2.2	18.3	41.1	140	268
165	386	177.5	35.2	2.2	18.8	41.7	140	275
175	401	182.7	36.3	2.2	19.4	42.3	140	283

A28. Pacific Northwest, Westside, Douglas-fir, high productivity sites (growth rate greater than 165 cubic feet wood per acre per year), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	67	0
5	0	22.3	0.0	4.0	0.0	3.6	67	30
15	20	29.5	0.2	3.9	1.3	10.0	75	45
25	132	69.7	0.8	3.6	5.8	15.4	82	95
35	348	145.0	1.8	3.3	13.6	20.2	86	184
45	564	216.4	2.8	3.1	21.0	24.4	87	268
55	768	281.2	3.7	3.1	27.6	28.0	88	344
65	941	333.6	4.4	3.0	33.0	31.3	88	405
75	1080	374.4	5.0	3.0	37.2	34.2	88	454
85	1199	408.4	5.5	2.9	40.6	36.9	89	494
95	1302	437.1	5.9	2.9	43.6	39.3	89	529
105	1393	461.7	6.2	2.9	46.1	41.4	89	558

A29. Pacific Northwest, Westside, Douglas-fir, high productivity sites (growth rate greater than 165 cubic feet wood per acre per year), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	67	0
5	0	22.3	0.0	4.0	0.0	3.6	67	30
15	20	29.5	0.2	3.9	1.3	10.0	75	45
25	170	83.3	0.9	3.5	7.1	15.4	82	110
35	446	177.8	2.3	3.2	16.9	20.2	86	220
45	719	265.8	3.5	3.1	25.9	24.4	87	323
55	924	328.6	4.4	3.0	32.4	28.0	88	396
65	1086	376.2	5.0	3.0	37.3	31.3	88	453
75	1226	415.8	5.6	2.9	41.3	34.2	88	500
85	1347	449.3	6.0	2.9	44.7	36.9	89	540
95	1452	477.7	6.4	2.9	47.6	39.3	89	574
105	1544	502.0	6.8	2.9	50.1	41.4	89	603

A30. Pacific Northwest, Westside, Douglas-fir medium productivity sites (growth rate between 120 and 164 cubic feet wood per acre per year), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	67	0
5	0	22.3	0.0	4.0	0.0	3.6	67	30
15	31	33.6	0.2	3.8	1.7	10.0	75	49
25	63	45.3	0.4	3.7	3.3	15.4	82	68
35	228	103.6	1.2	3.4	9.5	20.2	86	138
45	396	161.3	2.1	3.2	15.5	24.4	87	206
55	557	214.4	2.8	3.1	21.0	28.0	88	269
65	707	262.1	3.5	3.1	25.9	31.3	88	326
75	831	300.5	4.0	3.0	29.8	34.2	88	372
85	930	330.4	4.4	3.0	32.9	36.9	89	408
95	1014	355.2	4.8	3.0	35.4	39.3	89	438
105	1086	376.2	5.1	3.0	37.5	41.4	89	463

A31. Pacific Northwest, Westside, Douglas-fir, medium productivity sites (growth rate between 120 and 164 cubic feet wood per acre per year), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	67	0
5	0	22.3	0.0	4.0	0.0	3.6	67	30
15	31	33.6	0.2	3.8	1.7	10.0	75	49
25	79	50.8	0.5	3.7	3.9	15.4	82	74
35	273	119.4	1.5	3.4	11.1	20.2	86	155
45	494	193.7	2.5	3.2	18.7	24.4	87	242
55	689	256.3	3.4	3.1	25.2	28.0	88	316
65	836	301.9	4.0	3.0	29.8	31.3	88	370
75	955	337.8	4.5	3.0	33.5	34.2	88	413
85	1053	366.5	4.9	3.0	36.5	36.9	89	448
95	1137	390.7	5.3	2.9	38.9	39.3	89	477
105	1210	411.4	5.5	2.9	41.0	41.4	89	502

A32. Pacific Northwest, Westside, Fir & Spruce, high productivity sites

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	105	0
5	0	24.3	0.0	3.5	0.0	5.5	105	33
15	55	48.0	5.7	3.1	2.7	13.6	117	73
25	112	71.7	11.2	2.9	5.2	19.4	128	110
35	173	96.7	16.8	2.8	7.8	23.8	134	148
45	236	121.3	22.2	2.7	10.2	27.2	136	184
55	297	144.6	27.2	2.6	12.5	29.9	137	217
65	355	166.1	31.8	2.5	14.5	32.1	138	247
75	409	185.5	36.0	2.5	16.4	33.9	138	274
85	458	202.8	39.6	2.5	18.0	35.4	138	298
95	502	218.0	42.8	2.4	19.4	36.8	138	319
105	541	231.1	45.5	2.4	20.6	37.9	138	338
115	575	242.3	47.9	2.4	21.6	38.9	138	353
125	604	251.7	49.9	2.4	22.5	39.8	138	366
135	629	259.5	51.5	2.4	23.2	40.6	138	377
145	648	265.8	52.8	2.4	23.8	41.3	138	386
155	664	270.6	53.8	2.3	24.2	41.9	138	393
165	675	274.1	54.5	2.3	24.6	42.5	138	398
175	683	276.5	55.0	2.3	24.8	43.0	138	402

A33. Pacific Northwest, Westside, Fir & Spruce, medium productivity sites

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	104	0
5	0	24.3	0.0	3.5	0.0	5.5	104	33
15	24	34.9	3.1	3.3	1.5	13.6	116	56
25	50	45.7	6.0	3.1	2.9	19.4	127	77
35	77	57.3	8.9	3.0	4.3	23.8	133	97
45	105	68.9	11.7	2.9	5.5	27.2	135	116
55	132	80.1	14.4	2.9	6.7	29.9	136	134
65	158	90.5	16.8	2.8	7.8	32.1	137	150
75	182	100.1	18.9	2.8	8.7	33.9	137	164
85	204	108.8	20.9	2.7	9.6	35.4	137	177
95	223	116.5	22.6	2.7	10.3	36.8	137	189
105	241	123.3	24.0	2.7	10.9	37.9	137	199
115	256	129.1	25.3	2.6	11.5	38.9	137	207
125	269	134.0	26.4	2.6	12.0	39.8	137	215
135	280	138.1	27.3	2.6	12.3	40.6	137	221
145	288	141.4	28.0	2.6	12.6	41.3	137	226
155	295	144.0	28.5	2.6	12.9	41.9	137	230
165	300	145.9	28.9	2.6	13.1	42.5	137	233
175	304	147.2	29.2	2.6	13.2	43.0	137	235

A34. Pacific Northwest, Westside, Red Alder, high productivity sites

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	60	0
5	0	21.8	0.0	4.0	0.0	1.8	60	28
15	98	52.0	1.0	3.3	4.0	4.4	66	65
25	240	93.7	2.3	2.9	8.5	6.2	73	114
35	396	136.6	3.5	2.6	12.8	7.6	76	163
45	530	171.2	4.4	2.5	16.1	8.6	78	203
55	647	199.6	5.2	2.4	18.9	9.4	78	236
65	751	223.7	5.9	2.3	21.2	10.1	78	263
75	846	244.8	6.5	2.3	23.2	10.7	78	287
85	936	264.0	7.0	2.2	25.0	11.1	79	309
95	1023	281.9	7.4	2.2	26.7	11.5	79	330
105	1110	299.0	7.9	2.2	28.3	11.9	79	349
115	1196	315.4	8.3	2.2	29.9	12.2	79	368
125	1283	331.2	8.7	2.1	31.4	12.4	79	386
135	1369	346.3	9.1	2.1	32.8	12.6	79	403
145	1455	360.9	9.5	2.1	34.2	12.9	79	420
155	1539	374.6	9.9	2.1	35.5	13.0	79	435
165	1618	386.9	10.2	2.1	36.7	13.2	79	449
175	1687	397.5	10.5	2.0	37.7	13.4	79	461

A35. Pacific Northwest, Westside, Red Alder, medium productivity sites

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	60	0
5	0	21.8	0.0	4.0	0.0	1.8	60	28
15	118	58.1	1.2	3.2	4.6	4.4	66	71
25	213	86.1	2.1	2.9	7.8	6.2	73	105
35	331	119.2	3.0	2.7	11.1	7.6	76	144
45	452	151.2	3.9	2.6	14.3	8.6	78	181
55	563	179.4	4.7	2.5	17.0	9.4	78	213
65	661	203.1	5.3	2.4	19.2	10.1	78	240
75	751	223.7	5.9	2.3	21.2	10.7	78	264
85	838	243.2	6.4	2.3	23.0	11.1	79	286
95	926	261.9	6.9	2.3	24.8	11.5	79	307
105	1013	279.9	7.4	2.2	26.5	11.9	79	328
115	1100	297.2	7.8	2.2	28.2	12.2	79	348
125	1188	313.9	8.3	2.2	29.7	12.4	79	366
135	1275	329.9	8.7	2.1	31.3	12.6	79	385
145	1363	345.3	9.1	2.1	32.7	12.9	79	402
155	1450	360.1	9.5	2.1	34.1	13.0	79	419
165	1538	374.4	9.9	2.1	35.5	13.2	79	435
175	1625	388.1	10.2	2.1	36.8	13.4	79	451

A36. Pacific Northwest, Westside, Western Hemlock, high productivity sites (growth rate greater than 225 cubic feet wood per acre per year)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	118	0
5	0	27.2	0.0	3.9	0.0	3.6	118	35
15	80	53.6	4.3	3.4	3.3	10.0	131	74
25	154	77.3	8.1	3.1	6.2	15.4	144	110
35	502	181.4	22.6	2.6	16.8	20.2	150	244
45	873	280.5	36.3	2.4	26.9	24.4	153	370
55	1176	353.3	46.4	2.2	34.3	28.0	154	464
65	1437	410.4	54.4	2.2	40.0	31.3	155	538
75	1649	453.6	60.4	2.3	44.4	34.2	155	595
85	1796	481.8	64.3	2.4	47.3	36.9	155	633
95	1925	505.4	67.6	2.5	49.7	39.3	155	665
105	2032	524.3	70.3	2.6	51.6	41.4	155	690

A37. Pacific Northwest, Westside, Western Hemlock, medium productivity sites (growth rate between 120 and 224 cubic feet wood per acre per year)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	118	0
5	0	27.2	0.0	3.9	0.0	3.6	118	35
15	48	42.9	2.8	3.5	2.3	10.0	131	62
25	101	60.2	5.8	3.3	4.5	15.4	144	89
35	334	132.6	16.0	2.8	12.0	20.2	150	184
45	616	213.3	27.2	2.5	20.3	24.4	153	288
55	880	282.4	36.9	2.3	27.3	28.0	154	377
65	1112	338.6	44.7	2.3	33.0	31.3	155	450
75	1307	382.6	50.8	2.2	37.4	34.2	155	507
85	1456	414.4	55.2	2.2	40.6	36.9	155	549
95	1574	438.7	58.6	2.2	43.1	39.3	155	582
105	1682	460.0	61.6	2.3	45.2	41.4	155	611

A38. Rocky Mountain, North, Douglas-fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	71	0
5	0	20.2	0.0	3.5	0.0	5.2	71	29
15	9	24.4	1.2	3.3	0.5	13.0	79	42
25	21	30.3	2.5	3.0	1.1	18.6	87	56
35	46	41.9	4.7	2.7	2.0	22.9	91	74
45	93	63.6	8.5	2.3	3.5	26.2	92	104
55	152	89.6	12.9	2.1	5.2	28.9	93	139
65	204	111.7	16.6	1.9	6.6	31.1	93	168
75	247	129.5	19.6	1.8	7.8	33.0	93	192
85	285	145.0	22.2	1.7	8.8	34.5	94	212
95	320	158.7	24.5	1.7	9.7	35.9	94	230
105	350	170.4	26.5	1.6	10.5	37.0	94	246
115	377	180.6	28.2	1.6	11.1	38.0	94	260
125	401	189.7	29.7	1.6	11.7	39.0	94	272
135	424	198.0	31.1	1.5	12.3	39.8	94	283
145	446	205.8	32.4	1.5	12.8	40.5	94	293
155	467	213.3	33.6	1.5	13.2	41.1	94	303
165	485	219.7	34.7	1.5	13.6	41.7	94	311
175	499	224.6	35.5	1.5	13.9	42.3	94	318

A39. Rocky Mountain, North, Fir & Spruce

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	103	0
5	0	16.1	0.0	3.5	0.0	5.2	104	25
15	13	20.9	1.8	3.2	0.8	13.0	115	40
25	25	25.3	3.5	3.0	1.5	18.6	126	52
35	56	36.8	6.8	2.7	2.9	22.9	132	72
45	116	58.2	12.6	2.3	5.2	26.2	134	105
55	193	85.5	19.8	2.1	8.1	28.9	135	144
65	269	111.0	26.4	1.9	10.7	31.1	136	181
75	331	131.5	31.8	1.8	12.9	33.0	136	211
85	381	147.7	36.1	1.7	14.6	34.5	136	235
95	418	159.2	39.2	1.7	15.8	35.9	136	252
105	446	168.1	41.5	1.7	16.7	37.0	136	265
115	467	174.6	43.3	1.7	17.4	38.0	136	275
125	483	179.5	44.6	1.6	17.9	39.0	136	283
135	497	183.7	45.8	1.6	18.4	39.8	136	289
145	508	187.1	46.7	1.6	18.7	40.5	136	295
155	516	189.4	47.3	1.6	19.0	41.1	136	298
165	521	190.9	47.7	1.6	19.1	41.7	136	301
175	524	192.0	48.0	1.6	19.3	42.3	136	303

A40. Rocky Mountain, North, Lodgepole Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	50	0
5	0	20.3	0.0	2.9	0.0	2.4	50	26
15	15	24.5	1.6	2.6	0.5	6.4	55	36
25	34	29.8	3.2	2.4	1.0	9.8	61	46
35	62	37.6	5.4	2.1	1.6	12.6	63	59
45	123	53.8	9.2	1.8	2.7	14.9	65	82
55	189	71.1	13.2	1.6	3.8	17.0	65	107
65	236	83.1	16.0	1.4	4.5	18.7	65	124
75	281	94.3	18.6	1.3	5.2	20.3	65	140
85	322	104.4	20.9	1.3	5.9	21.7	65	154
95	360	113.6	23.0	1.2	6.4	22.9	65	167
105	395	121.8	24.9	1.2	6.9	24.0	65	179
115	426	129.0	26.5	1.2	7.4	25.0	65	189
125	452	134.9	27.9	1.1	7.7	25.8	65	197
135	470	138.9	28.8	1.1	8.0	26.7	65	204
145	477	140.5	29.2	1.1	8.1	27.4	65	206

A41. Rocky Mountain, North, Ponderosa Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	53	0
5	0	14.6	0.0	3.2	0.0	2.4	53	20
15	12	18.7	0.6	3.0	0.6	6.4	59	29
25	30	24.8	1.4	2.7	1.4	9.8	65	40
35	63	35.6	2.6	2.4	2.5	12.6	67	56
45	101	47.8	3.9	2.2	3.7	14.9	69	72
55	132	57.8	5.0	2.0	4.7	17.0	69	86
65	161	66.9	5.9	1.9	5.5	18.7	69	99
75	187	74.9	6.8	1.8	6.3	20.3	70	110
85	211	82.1	7.6	1.8	7.0	21.7	70	120
95	231	88.2	8.2	1.7	7.6	22.9	70	129
105	249	93.6	8.8	1.7	8.1	24.0	70	136
115	265	98.4	9.3	1.7	8.5	25.0	70	143
125	279	102.5	9.7	1.7	8.9	25.8	70	149
135	289	105.5	10.0	1.6	9.2	26.7	70	153
145	298	108.0	10.3	1.6	9.4	27.4	70	157
155	306	110.4	10.6	1.6	9.6	28.1	70	160
165	313	112.4	10.8	1.6	9.8	28.7	70	163
175	318	113.8	10.9	1.6	9.9	29.3	70	166

A42. Rocky Mountain, South, Douglas-fir

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	67	0
5	0	20.2	0.0	4.2	0.0	5.2	67	30
15	9	24.7	1.2	3.3	0.7	13.0	75	43
25	15	27.2	2.0	2.9	1.1	18.6	82	52
35	21	30.4	2.9	2.6	1.6	22.9	86	60
45	33	35.8	4.1	2.1	2.1	26.2	87	70
55	51	44.2	5.7	1.6	2.9	28.9	88	83
65	75	55.3	7.6	1.2	3.9	31.1	88	99
75	100	66.6	9.6	1.0	4.8	33.0	88	115
85	121	76.1	11.3	0.8	5.6	34.5	88	128
95	140	84.5	12.7	0.7	6.3	35.9	89	140
105	156	91.6	14.0	0.7	6.9	37.0	89	150
115	169	97.2	14.9	0.6	7.3	38.0	89	158
125	181	101.9	15.8	0.6	7.7	39.0	89	165
135	190	105.9	16.5	0.6	8.0	39.8	89	171
145	197	109.1	17.0	0.5	8.3	40.5	89	175
155	204	111.9	17.5	0.6	8.5	41.1	89	180
165	209	114.1	17.9	0.6	8.7	41.7	89	183
175	214	116.1	18.3	0.6	8.9	42.3	89	186

A43. Rocky Mountain, South, Fir & Spruce

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	103	0
5	0	16.1	0.0	3.6	0.0	5.2	104	25
15	4	17.7	1.0	3.4	0.4	13.0	115	36
25	14	21.3	2.5	3.1	0.9	18.6	126	46
35	36	29.5	5.0	2.6	1.7	22.9	132	62
45	56	36.7	7.2	2.3	2.4	26.2	134	75
55	82	46.3	9.9	2.0	3.2	28.9	135	90
65	117	58.6	13.3	1.7	4.3	31.1	136	109
75	149	69.9	16.3	1.6	5.2	33.0	136	126
85	182	81.4	19.4	1.4	6.2	34.5	136	143
95	212	91.7	22.2	1.3	7.1	35.9	136	158
105	248	104.0	25.4	1.2	8.1	37.0	136	176
115	282	115.3	28.4	1.2	9.0	38.0	136	192
125	316	126.5	31.3	1.1	9.9	39.0	136	208
135	350	137.8	34.2	1.1	10.8	39.8	136	224
145	376	146.1	36.4	1.0	11.4	40.5	136	235
155	401	153.9	38.4	1.0	12.1	41.1	136	246
165	427	162.1	40.5	1.0	12.7	41.7	136	258
175	447	168.4	42.1	0.9	13.2	42.3	136	267

A44. Rocky Mountain, South, Lodgepole Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	47	0
5	0	20.3	0.0	3.0	0.0	2.4	48	26
15	0	20.3	0.7	3.0	0.4	6.4	53	31
25	9	22.7	1.8	2.7	1.0	9.8	58	38
35	25	27.1	3.2	2.4	1.7	12.6	60	47
45	49	33.9	5.0	2.0	2.5	14.9	62	58
55	88	44.4	7.5	1.7	3.7	17.0	62	74
65	132	56.2	10.3	1.4	5.0	18.7	62	92
75	179	68.5	13.2	1.2	6.3	20.3	62	110
85	229	81.3	16.1	1.1	7.7	21.7	62	128
95	276	93.0	18.7	1.0	8.9	22.9	62	144
105	314	102.4	20.8	0.9	9.9	24.0	62	158
115	346	110.0	22.5	0.9	10.7	25.0	62	169
125	370	115.8	23.9	0.8	11.3	25.8	62	178
135	387	119.8	24.8	0.8	11.7	26.7	62	184
145	395	121.7	25.3	0.8	11.9	27.4	62	187

A45. Rocky Mountain, South, Ponderosa Pine

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	53	0
5	0	14.6	0.0	3.5	0.0	2.4	54	20
15	14	19.2	0.7	2.9	0.6	6.4	59	30
25	18	20.6	1.0	2.7	0.9	9.8	65	35
35	25	22.9	1.4	2.5	1.3	12.6	68	41
45	38	27.3	1.9	2.2	1.8	14.9	69	48
55	56	33.3	2.6	1.9	2.4	17.0	70	57
65	74	39.2	3.3	1.7	2.9	18.7	70	66
75	91	44.7	3.9	1.5	3.4	20.3	70	74
85	107	49.8	4.4	1.4	3.9	21.7	70	81
95	122	54.6	5.0	1.3	4.3	22.9	70	88
105	139	60.1	5.5	1.2	4.8	24.0	70	96
115	153	64.4	6.0	1.2	5.2	25.0	70	102
125	168	68.9	6.5	1.1	5.6	25.8	70	108
135	183	73.6	7.0	1.1	6.0	26.7	70	114
145	198	78.3	7.4	1.0	6.4	27.4	70	121
155	213	82.8	7.9	1.0	6.8	28.1	70	127
165	227	87.0	8.3	0.9	7.1	28.7	70	132
175	240	90.8	8.7	0.9	7.4	29.3	70	137

A46. South Central, Lowland Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	112	0
5	0	29.3	0.0	1.7	0.0	1.1	112	32
10	11	34.7	1.0	1.7	1.1	2.1	117	41
15	23	40.2	1.8	1.7	1.9	3.0	124	49
20	39	47.9	2.6	1.6	2.7	3.7	131	59
25	54	54.9	3.2	1.6	3.3	4.4	137	67
30	71	62.9	3.8	1.6	3.9	5.0	140	77
35	87	70.3	4.3	1.6	4.4	5.5	142	86
40	104	77.9	4.7	1.6	4.9	6.0	144	95
45	121	85.9	5.0	1.5	5.4	6.4	145	104
50	138	93.4	5.3	1.5	5.9	6.8	146	113
55	155	100.9	5.4	1.5	6.4	7.2	146	121
60	172	108.8	5.5	1.5	6.9	7.5	146	130
65	189	116.1	5.6	1.5	7.3	7.8	147	138
70	205	123.3	5.6	1.5	7.8	8.1	147	146
75	219	129.4	5.5	1.5	8.2	8.4	147	153
80	234	135.9	5.5	1.5	8.6	8.6	147	160
85	249	142.2	5.4	1.5	9.0	8.9	147	167
90	264	148.4	5.3	1.5	9.4	9.1	147	174

A47. South Central, Natural Pine, high productivity sites (greater than 120 cu ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	71	0
5	0	18.5	0.0	4.1	0.0	3.2	71	26
10	20	25.9	0.5	3.7	0.8	5.5	74	36
15	47	35.8	1.0	3.4	1.7	7.3	79	49
20	76	46.1	1.6	3.2	2.6	8.7	83	62
25	108	57.6	2.2	3.0	3.5	9.8	86	76
30	140	68.7	2.7	2.9	4.4	10.7	89	89
35	173	80.0	3.1	2.8	5.2	11.5	90	103
40	205	90.9	3.5	2.7	6.0	12.2	91	115
45	238	101.8	3.8	2.6	6.8	12.7	92	128
50	268	111.6	3.9	2.6	7.5	13.2	92	139
55	297	121.3	4.0	2.5	8.2	13.7	93	150
60	327	130.8	3.9	2.5	8.9	14.1	93	160
65	356	140.0	3.8	2.4	9.5	14.4	93	170
70	379	147.2	3.6	2.4	10.0	14.7	93	178
75	402	154.4	3.4	2.4	10.5	15.0	93	186
80	423	160.8	3.1	2.3	11.0	15.2	93	192
85	444	167.2	2.8	2.3	11.4	15.5	93	199
90	462	172.5	2.6	2.3	11.8	15.7	93	205

A48. South Central, Natural Pine, medium productivity sites (50 and 119 cu ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	73	0
5	0	18.5	0.0	4.1	0.0	3.2	73	26
10	18	25.2	0.5	3.8	0.8	5.5	76	36
15	35	31.3	0.9	3.6	1.4	7.3	81	44
20	56	38.9	1.3	3.4	2.1	8.7	86	54
25	80	47.4	1.7	3.2	2.8	9.8	89	65
30	105	56.2	2.2	3.1	3.5	10.7	92	76
35	131	65.4	2.6	2.9	4.2	11.5	93	87
40	161	75.7	3.0	2.8	5.0	12.2	94	99
45	186	84.4	3.4	2.8	5.6	12.7	95	109
50	212	93.2	3.6	2.7	6.3	13.2	95	119
55	236	101.2	3.8	2.6	6.8	13.7	96	128
60	260	109.2	4.0	2.6	7.4	14.1	96	137
65	282	116.1	4.0	2.5	7.9	14.4	96	145
70	303	123.2	4.0	2.5	8.4	14.7	96	153
75	322	129.1	4.0	2.5	8.8	15.0	96	159
80	339	134.7	3.9	2.4	9.2	15.2	96	165
85	355	139.7	3.8	2.4	9.5	15.5	96	171
90	369	144.1	3.7	2.4	9.8	15.7	96	176

A49. South Central, Oak-Pine, high productivity sites (greater than 120 cu ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	62	0
5	0	19.9	0.0	3.8	0.0	3.1	62	27
10	23	29.8	0.8	3.5	1.1	5.1	64	40
15	40	37.4	1.4	3.4	1.9	6.6	69	51
20	56	44.6	1.9	3.3	2.6	7.7	73	60
25	75	52.5	2.5	3.2	3.3	8.5	76	70
30	97	62.0	3.1	3.1	4.1	9.2	78	81
35	119	71.4	3.6	3.0	4.9	9.8	79	93
40	142	81.0	4.1	2.9	5.7	10.2	80	104
45	164	90.5	4.6	2.8	6.4	10.6	80	115
50	187	99.9	4.9	2.8	7.1	11.0	81	126
55	210	109.3	5.1	2.7	7.8	11.3	81	136
60	234	119.0	5.2	2.7	8.5	11.5	81	147
65	257	128.6	5.2	2.7	9.3	11.8	81	158
70	282	138.6	5.0	2.6	10.0	12.0	81	168
75	307	148.5	4.7	2.6	10.7	12.1	81	179
80	330	157.6	4.2	2.6	11.4	12.3	81	188
85	353	166.3	3.7	2.5	12.0	12.5	81	197
90	374	174.5	3.2	2.5	12.6	12.6	81	205

A50. South Central, Oak-Pine, medium productivity sites (between 50 and 119 cu ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	62	0
5	0	19.9	0.0	3.8	0.0	3.1	62	27
10	10	24.6	0.5	3.7	0.7	5.1	64	34
15	24	30.7	1.0	3.5	1.4	6.6	69	43
20	38	36.8	1.5	3.4	2.0	7.7	73	51
25	54	43.4	2.0	3.3	2.7	8.5	76	60
30	69	49.8	2.4	3.2	3.3	9.2	78	68
35	88	58.2	2.9	3.1	3.9	9.8	79	78
40	108	66.8	3.4	3.0	4.6	10.2	80	88
45	129	75.8	3.9	2.9	5.3	10.6	80	99
50	149	83.9	4.3	2.9	6.0	11.0	81	108
55	168	92.1	4.7	2.8	6.6	11.3	81	118
60	189	100.7	5.0	2.8	7.2	11.5	81	127
65	209	109.0	5.2	2.7	7.8	11.8	81	137
70	229	117.1	5.3	2.7	8.4	12.0	81	146
75	247	124.2	5.3	2.7	9.0	12.1	81	153
80	262	130.6	5.2	2.7	9.4	12.3	81	160
85	275	135.5	5.1	2.6	9.8	12.5	81	166
90	283	139.0	5.0	2.6	10.1	12.6	81	169

A51. South Central, Planted Pine, high productivity sites (greater than 120 cu ft/ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	72	0
5	0	14.2	0.0	4.0	0.0	3.2	73	21
10	48	32.8	0.8	3.9	0.9	5.5	76	44
15	147	69.5	2.1	3.8	2.4	7.3	80	85
20	245	103.7	3.4	3.7	3.8	8.7	85	123
25	315	126.8	4.3	3.7	4.7	9.8	88	149
30	347	137.0	4.7	3.7	5.2	10.7	91	161
35	352	138.3	4.8	3.7	5.3	11.5	92	164
40	355	139.4	4.8	3.7	5.3	12.2	93	165
45	359	140.5	4.9	3.7	5.4	12.7	94	167
50	362	141.6	5.0	3.7	5.4	13.2	94	169

A52. South Central, Planted Pine, high productivity sites (greater than 120 cu ft/ac/yr), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	72	0
5	0	14.2	0.0	4.0	0.0	3.2	73	21
10	78	44.4	1.2	3.9	1.3	5.5	76	56
15	227	97.7	3.1	3.8	3.5	7.3	80	115
20	350	137.7	4.6	3.7	5.1	8.7	85	160
25	429	162.0	5.6	3.7	6.1	9.8	88	187
30	462	171.6	5.9	3.7	6.5	10.7	91	198
35	464	172.2	6.0	3.7	6.6	11.5	92	200
40	466	172.8	6.0	3.7	6.6	12.2	93	201
45	468	173.4	6.1	3.7	6.7	12.7	94	203
50	470	174.0	6.1	3.7	6.7	13.2	94	204

A53. South Central, Planted Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	72	0
5	0	14.2	0.0	4.0	0.0	3.2	73	21
10	28	25.1	0.5	3.9	0.6	5.5	76	36
15	95	50.6	1.5	3.8	1.6	7.3	81	65
20	165	76.0	2.4	3.8	2.7	8.7	85	94
25	219	95.0	3.2	3.8	3.5	9.8	89	115
30	252	106.2	3.6	3.7	4.0	10.7	91	128
35	260	108.9	3.7	3.7	4.1	11.5	92	132
40	263	109.7	3.8	3.7	4.2	12.2	93	134
45	265	110.5	3.8	3.7	4.2	12.7	94	135
50	268	111.4	3.9	3.7	4.3	13.2	94	136

A54. South Central, Planted Pine, medium productivity sites (growth rate between 50 and 119 cubic feet wood per acre per year), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	72	0
5	0	14.2	0.0	4.0	0.0	3.2	73	21
10	45	31.7	0.7	3.9	0.8	5.5	76	43
15	152	71.4	2.2	3.8	2.5	7.3	81	87
20	255	107.1	3.5	3.7	3.9	8.7	85	127
25	321	128.7	4.4	3.7	4.8	9.8	89	151
30	354	139.1	4.8	3.7	5.3	10.7	91	164
35	360	141.1	4.9	3.7	5.4	11.5	92	167
40	362	141.5	4.9	3.7	5.4	12.2	93	168
45	363	141.9	5.0	3.7	5.4	12.7	94	169
50	364	142.4	5.0	3.7	5.5	13.2	94	170

A55. South Central, Upland Hardwoods

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	64	0
5	0	24.4	0.0	3.8	0.0	1.1	65	29
10	16	32.4	0.8	3.6	1.2	2.1	67	40
15	31	40.3	1.5	3.4	2.2	3.0	72	50
20	47	48.1	2.1	3.3	2.9	3.7	76	60
25	64	56.6	2.7	3.1	3.6	4.4	79	70
30	80	64.5	3.2	3.0	4.2	5.0	81	80
35	98	73.3	3.7	2.9	4.8	5.5	82	90
40	116	81.8	4.1	2.9	5.4	6.0	83	100
45	135	91.5	4.5	2.8	6.1	6.4	84	111
50	156	101.4	4.8	2.7	6.7	6.8	84	122
55	176	111.0	5.0	2.7	7.4	7.2	84	133
60	195	119.9	5.0	2.6	8.0	7.5	84	143
65	213	128.6	5.0	2.6	8.6	7.8	84	153
70	230	136.5	4.8	2.5	9.1	8.1	85	161
75	247	144.4	4.7	2.5	9.6	8.4	85	170
80	262	151.6	4.4	2.5	10.1	8.6	85	177
85	279	159.1	4.2	2.5	10.6	8.9	85	185
90	292	165.2	3.9	2.4	11.0	9.1	85	192

A56. Southeast, Lowland Hardwood

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	113	0
5	0	23.5	0.0	1.7	0.0	1.1	113	26
10	11	28.7	0.3	1.7	1.0	2.1	118	34
15	23	33.9	0.6	1.7	1.7	3.0	125	41
20	39	41.4	0.9	1.7	2.4	3.7	132	50
25	54	48.2	1.2	1.6	2.9	4.4	138	58
30	71	55.9	1.5	1.6	3.5	5.0	141	67
35	87	63.1	1.7	1.6	4.0	5.5	144	76
40	104	70.4	2.0	1.6	4.4	6.0	145	84
45	121	78.3	2.2	1.6	5.0	6.4	146	93
50	138	85.6	2.4	1.5	5.4	6.8	147	102
55	155	92.9	2.6	1.5	5.9	7.2	147	110
60	172	100.7	2.7	1.5	6.4	7.5	148	119
65	189	107.8	2.9	1.5	6.9	7.8	148	127
70	205	114.9	3.0	1.5	7.3	8.1	148	135
75	219	120.9	3.1	1.5	7.7	8.4	148	142
80	234	127.3	3.1	1.5	8.1	8.6	148	149
85	249	133.6	3.2	1.5	8.5	8.9	148	156
90	264	139.8	3.2	1.5	8.9	9.1	148	162

A57. Southeast, Natural Pine, high productivity sites (greater than 85 cu ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	78	0
5	0	14.4	0.0	3.8	0.0	3.2	78	21
10	20	21.9	0.2	3.6	0.9	5.5	82	32
15	47	31.9	0.5	3.4	1.9	7.3	87	45
20	76	42.4	0.7	3.2	2.9	8.7	92	58
25	108	54.2	1.0	3.1	4.0	9.8	96	72
30	140	65.8	1.2	3.0	5.0	10.7	98	86
35	173	77.5	1.4	2.9	6.1	11.5	100	99
40	205	89.1	1.6	2.9	7.1	12.2	101	113
45	238	100.6	1.7	2.8	8.0	12.7	102	126
50	268	111.1	1.8	2.8	8.9	13.2	102	138
55	297	121.5	1.9	2.7	9.8	13.7	102	150
60	327	131.8	2.0	2.7	10.6	14.1	103	161
65	356	141.9	2.1	2.7	11.5	14.4	103	173
70	379	149.7	2.2	2.6	12.1	14.7	103	181
75	402	157.7	2.2	2.6	12.8	15.0	103	190
80	423	164.9	2.2	2.6	13.3	15.2	103	198
85	444	172.0	2.3	2.6	13.9	15.5	103	206
90	462	177.9	2.3	2.6	14.4	15.7	103	213

A58. Southeast, Natural Pine, medium productivity sites (between 50 and 84 cu ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	79	0
5	0	14.4	0.0	3.8	0.0	3.2	79	21
10	18	21.2	0.2	3.6	0.8	5.5	82	31
15	35	27.3	0.4	3.4	1.5	7.3	88	40
20	56	35.1	0.6	3.3	2.3	8.7	93	50
25	80	43.7	0.8	3.2	3.2	9.8	97	61
30	105	52.8	1.0	3.1	4.0	10.7	99	72
35	131	62.3	1.2	3.0	4.8	11.5	101	83
40	161	73.1	1.3	3.0	5.8	12.2	102	95
45	186	82.2	1.5	2.9	6.5	12.7	103	106
50	212	91.5	1.6	2.9	7.3	13.2	103	117
55	236	100.0	1.7	2.8	8.0	13.7	103	126
60	260	108.5	1.8	2.8	8.7	14.1	104	136
65	282	116.0	1.9	2.8	9.4	14.4	104	144
70	303	123.6	2.0	2.7	10.0	14.7	104	153
75	322	130.0	2.0	2.7	10.5	15.0	104	160
80	339	136.1	2.1	2.7	11.0	15.2	104	167
85	355	141.5	2.1	2.7	11.5	15.5	104	173
90	369	146.3	2.1	2.7	11.8	15.7	104	179

A59. Southeast, Oak-Pine, high productivity sites (greater than 85 cu ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	62	0
5	0	14.2	0.0	3.8	0.0	3.1	62	21
10	23	25.1	0.4	3.5	0.9	5.1	64	35
15	40	33.3	0.7	3.4	1.6	6.6	69	46
20	56	41.1	1.0	3.3	2.2	7.7	73	55
25	75	49.6	1.2	3.3	2.9	8.5	76	65
30	97	59.7	1.5	3.2	3.6	9.2	78	77
35	119	69.8	1.7	3.1	4.3	9.8	79	89
40	142	79.9	1.8	3.1	4.9	10.2	80	100
45	164	90.0	1.9	3.0	5.6	10.6	80	111
50	187	99.9	2.0	3.0	6.3	11.0	81	122
55	210	109.6	1.9	3.0	6.9	11.3	81	133
60	234	119.7	1.9	2.9	7.6	11.5	81	144
65	257	129.7	1.8	2.9	8.2	11.8	81	154
70	282	139.9	1.7	2.9	8.9	12.0	81	165
75	307	149.9	1.5	2.9	9.5	12.1	81	176
80	330	159.2	1.3	2.9	10.1	12.3	81	186
85	353	168.0	1.2	2.8	10.7	12.5	81	195
90	374	176.2	1.0	2.8	11.2	12.6	81	204

A60. Southeast, Oak-Pine, medium productivity sites (between 50 and 84 cu ft/ac/yr)

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	62	0
5	0	14.2	0.0	3.8	0.0	3.1	62	5
10	10	19.3	0.2	3.7	0.5	5.1	64	10
15	24	26.0	0.5	3.5	1.1	6.6	69	15
20	38	32.6	0.7	3.4	1.7	7.7	73	20
25	54	39.7	1.0	3.4	2.2	8.5	76	25
30	69	46.7	1.2	3.3	2.7	9.2	78	30
35	88	55.7	1.4	3.2	3.4	9.8	79	35
40	108	64.9	1.6	3.2	4.0	10.2	80	40
45	129	74.5	1.8	3.1	4.6	10.6	80	45
50	149	83.0	1.9	3.1	5.2	11.0	81	50
55	168	91.7	1.9	3.0	5.8	11.3	81	55
60	189	100.6	2.0	3.0	6.3	11.5	81	60
65	209	109.3	2.0	3.0	6.9	11.8	81	65
70	229	117.8	1.9	3.0	7.5	12.0	81	70
75	247	125.1	1.9	2.9	7.9	12.1	81	75
80	262	131.7	1.8	2.9	8.3	12.3	81	80
85	275	136.7	1.7	2.9	8.7	12.5	81	85
90	283	140.3	1.7	2.9	8.9	12.6	81	90

A61. Southeast, Planted Pine, high productivity sites (greater than 85 cu ft/ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	79	0
5	0	12.4	0.0	4.0	0.0	3.2	79	20
10	48	30.8	0.3	3.8	0.8	5.5	82	41
15	147	67.4	0.8	3.7	2.3	7.3	88	81
20	245	101.9	1.3	3.7	3.6	8.7	93	119
25	315	125.6	1.6	3.7	4.6	9.8	97	145
30	347	136.1	1.7	3.7	5.0	10.7	99	157
35	352	137.5	1.8	3.6	5.1	11.5	101	159
40	355	138.6	1.8	3.6	5.1	12.2	102	161
45	359	139.7	1.8	3.6	5.2	12.7	103	163
50	362	140.9	1.8	3.6	5.2	13.2	103	165

A62. Southeast, Planted Pine, high productivity sites (greater than 85 cu ft/ac/yr), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	79	0
5	0	12.4	0.0	4.0	0.0	3.2	79	20
10	78	42.2	0.4	3.8	1.2	5.5	82	53
15	227	95.8	1.2	3.7	3.3	7.3	88	111
20	350	136.9	1.7	3.6	4.9	8.7	93	156
25	429	162.1	2.1	3.6	5.9	9.8	97	183
30	462	172.1	2.2	3.6	6.3	10.7	99	195
35	464	172.8	2.2	3.6	6.4	11.5	101	197
40	466	173.4	2.2	3.6	6.4	12.2	102	198
45	468	174.1	2.3	3.6	6.5	12.7	103	199
50	470	174.7	2.3	3.6	6.5	13.2	103	200

A63. Southeast, Planted Pine, medium productivity sites (between 50 and 84 cu ft/ac/yr), lower intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	82	0
5	0	12.4	0.0	4.0	0.0	3.2	82	20
10	28	23.1	0.2	3.9	0.5	5.5	85	33
15	95	48.4	0.5	3.8	1.5	7.3	91	62
20	165	73.9	0.9	3.7	2.6	8.7	96	90
25	219	93.2	1.2	3.7	3.3	9.8	100	111
30	252	104.5	1.3	3.7	3.8	10.7	103	124
35	260	107.3	1.4	3.7	3.9	11.5	104	128
40	263	108.1	1.4	3.7	4.0	12.2	105	129
45	265	108.9	1.4	3.7	4.0	12.7	106	131
50	268	109.8	1.4	3.7	4.1	13.2	107	132

A64. Southeast, Planted Pine, medium productivity sites (growth rate between 50 and 84 cubic feet wood per acre per year), higher intensity management

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	82	0
5	0	12.4	0.0	4.0	0.0	3.2	82	20
10	45	29.7	0.3	3.9	0.8	5.5	85	40
15	152	69.3	0.8	3.7	2.3	7.3	91	83
20	255	105.4	1.3	3.7	3.7	8.7	96	123
25	321	127.5	1.6	3.7	4.6	9.8	100	147
30	354	138.2	1.8	3.6	5.1	10.7	103	159
35	360	140.3	1.8	3.6	5.2	11.5	104	162
40	362	140.8	1.8	3.6	5.2	12.2	105	164
45	363	141.2	1.8	3.6	5.2	12.7	106	165
50	364	141.7	1.8	3.6	5.3	13.2	107	166

A65. Southeast, Upland Hardwoods

Age	Mean Volume	Mean Carbon Density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
Years	m^3/ha	Metric tons carbon per hectare						
0	0	0.0	0.0	0.0	0.0	0.0	64	0
5	0	21.5	0.0	3.7	0.0	1.1	64	26
10	16	29.6	0.4	3.5	1.0	2.1	67	37
15	31	37.6	0.8	3.4	1.8	3.0	72	47
20	47	45.6	1.1	3.2	2.5	3.7	76	56
25	64	54.1	1.4	3.1	3.1	4.4	79	66
30	80	62.0	1.7	3.1	3.6	5.0	81	75
35	98	70.9	1.9	3.0	4.2	5.5	82	85
40	116	79.4	2.1	2.9	4.7	6.0	83	95
45	135	89.1	2.2	2.8	5.3	6.4	84	106
50	156	99.0	2.3	2.8	5.9	6.8	84	117
55	176	108.7	2.3	2.7	6.5	7.2	84	127
60	195	117.5	2.3	2.7	7.0	7.5	84	137
65	213	126.2	2.2	2.7	7.5	7.8	84	146
70	230	134.1	2.1	2.6	8.0	8.1	84	155
75	247	141.9	2.0	2.6	8.4	8.4	85	163
80	262	149.0	1.9	2.6	8.9	8.6	85	171
85	279	156.4	1.7	2.6	9.3	8.9	85	179
90	292	162.5	1.6	2.5	9.7	9.1	85	185

Chapter 1, GHG Inventories: Part I
Appendix Section 2: Guidelines for Using Models

2.1 Introduction

Forest carbon accounting estimates are almost always based, at least in part, on models. Models are a simplification of a complex system, often coded into computer programs. For forestry applications, models usually consist of a series of mathematical equations designed to represent ecological processes of forests. In some cases models may be as simple as an equation based on a multiplier, such as multiplying dry weight biomass by 0.5 for an estimate of carbon.

Models are available for estimating carbon stocks and flows for forests at a variety of scales and for specific conditions and activities. Some models may be more accurate than look-up tables for specific activities or entities, but may require more effort and possibly a higher cost to apply.

Models may be useful tools for estimating both entity-wide carbon flows and activity-level accomplishments, but the estimates should be evaluated to be sure the models are appropriate for each application. The basic elements of model evaluation are described in section 2.3.

Before using a model, it is necessary to determine the area of land to be included in the estimate, and characterize that area in a way that is compatible with the estimates from the model. To achieve the best results, the selected model should be parameterized for the specific conditions of the land area to which the model is applied. Partitioning of the land area into relatively uniform strata may help in matching and parameterizing a model for a specific application.

2.2 Kinds of models

Two general classes of models can be used to estimate changes in carbon stocks. Entities may use either type of model provided the guidance in this section is followed.

Traditional empirical forestry models, developed to predict timber production (estimated in volume units), can be modified to predict carbon stocks or flows. The modification may be as simple as converting the estimated volume to carbon using standard coefficients or ratios from the literature (e.g., Hoover et al. 2000).

More recently, models that include representation of key ecosystem processes such as photosynthesis and respiration are becoming available. An appealing feature of such models is that they may be applied to conditions and treatments beyond those represented in the data used to develop the models; however, this extrapolation should be done cautiously with appropriate verification to ensure the accuracy of estimates. Ecosystem process models often produce outputs in units of mass (carbon). Many ecosystem process models have been developed for research applications, but this does not limit their use or potential for application to practical forest management issues (e.g., Battaglia and Sands 1998; Valentine 1999).

2.3 Model evaluation and documentation

Model evaluation and documentation are important steps in developing an inventory of forest carbon. The accuracy of carbon stock and flux estimates is in part a function of model performance in relation to conditions of the entity. Therefore, the following guidelines are provided for evaluating and documenting models chosen by the entity to estimate carbon stocks and flows.

These guidelines are based on an extensive review of how ecological or forestry-related models are evaluated for public policy (Prisley and Mortimer, in press). There are published standards for model evaluation for some applications. For example, the American Society for Testing and Materials (ASTM) has guides for groundwater flow models and standards for atmospheric dispersion model performance (ASTM, 2000, 2002).

No standards have yet been established specifically for forest carbon accounting; however, there is general guidance available for Federal agencies providing information. The Data Quality Act (Pub. L. No. 106-554, 114 Stat. 2763A-153 [2000]) requires that nearly all Federal agencies provide guidance to maximize integrity of information disseminated by the agency, and provides a mechanism to request a correction from the agency. As a result of the Data Quality Act, the Department of Agriculture (USDA, 2003, as cited in Prisley and Mortimer, in press) released guidance that includes the following:

> When creating estimates or forecasts that are derived from existing data sources *using models* or other techniques [emphasis added]:
>
> - Use sound statistical methods that conform to accepted professional standards.
> - Document models and other estimation or forecasting techniques to describe the data sources used and the methodologies and assumptions employed.

Prisley and Mortimer (in press) summarize criteria to be considered in determining appropriate use of a model, including listing model assumptions, limitations, and uncertainties; use of peer-review; and adequate empirical testing. Entities using models should follow these guidelines to receive a higher rating (see section 2.5):

1. The scope of the model should be clearly defined. This is the model domain, and can be expressed in terms of ecophysiographic regions, spatial scale, temporal scale, etc. The model application should then be limited to the domain for which a model has been developed and evaluated.
2. Models should be clearly documented. Documentation should include assumptions, known limitations, embedded hypotheses, assessment of uncertainties, and sources (for equations, data sets, factors or parameters, etc).
3. Models should be scientifically reviewed. A thorough peer review process would include evaluation of equations, modeling system, software, and calibration data set, for applicability and adequacy. In addition the review should be conducted not only by modeling specialists, but specialists in relevant fields of biology, ecology, physiology, etc.

4. When possible, model results should be compared with field observations and results of this comparison should be documented.
5. Sensitivity analysis should be conducted to examine model behavior across the range of parameters for which it is to be applied. Sensitivity analysis provides an understanding of model robustness, and helps increase a user's confidence in model results.
6. Model should be made available for testing/evaluation.
7. Because models are a function of the scientific understanding and data at the point in time at which the model was developed, they should be periodically reviewed in light of new knowledge and data. If necessary, models should be recalibrated based on this evaluation.
8. When models are applied for regulatory purposes or in policy development, a public comment period is critical.

Peer review is an important part of the model evaluation process. Although models used in the private sector may be confidential, the internal evaluation process should also follow standards for peer review. Recommendations for conducting scientific peer review from the Office of Management and Budget (as cited in Prisley and Mortimer, in press) include:

- peer reviewers be selected primarily on the basis of necessary technical expertise,
- peer reviewers be expected to disclose to agencies prior technical/policy positions they may have taken on the issues at hand,
- peer reviewers be expected to disclose to agencies their sources of personal and institutional funding (private or public sector), and
- peer reviews be conducted in an open and rigorous manner.

2.4 Validating models with field data

The data used to test the model results should be independent of the data used to parameterize the model. There are many kinds of statistical tests available for quantifying the conformance of model output with field data. Selection criteria for an appropriate statistical test should include the ability to quantify the percentage difference between the model output and the data at the 95% confidence level, or the ability to test a hypothesis that the difference between model output and the data is not greater than a specific percentage at the 95% confidence level.

2.5 Rating estimates from models

As discussed in the general forest inventory guidelines, the rating for using a model depends on how well the model represents the specific conditions of the land area, as determined by the model evaluation. If the model is a good fit, it should result in a "B" rating. A model that is developed specifically for the land conditions and management practices of the reporter may achieve a higher rating, especially if the model is validated following guidelines in section 2.4. To achieve an "A" rating from using a model for estimating changes in carbon stocks, comparison with field data from the area of model application is required. Use of an inappropriate model for the land characteristics and practices may result in a lower rating. The following table provides some more specific guidance about rating a model application:

Rating	*Points*	*Characterization*	*Typical Description for Forestry*
A	4	Most accurate method (within 10 % of true value)	Model is validated with data specific to the site conditions and management practices.
B	3	Adequate accuracy (within 20 % of true value)	Use of a model that is parameterized specifically for the site conditions and management practices.
C	2	Marginal accuracy (within 30 % of true value)	Use of a model that generally matches the site and management conditions. For example, a regional model for a forest type that is similar in application to a look-up table.
D	1	Inadequate accuracy	Use of global estimates.

2.6 References

American Society for Testing and Materials. 2000. *Standard Guide for Statistical evaluation of Atmospheric Dispersion Model Performance*. Standard D6589–00. West Conshohocken, Pennsylvania.

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Chapter 1, GHG Inventories: Part I
Appendix Section 3: Measurement Protocols for Forest Carbon Sequestration

3.1. Scope of Guidelines

The scope of this section is to provide guidance on protocols for measuring and monitoring carbon emissions or removals from forestry activities at both the entity and sub-entity scales. An entity could be involved in more than one sector, such as a utility company that has both forestry and power production activities. In the context of these guidelines, only the forestry sector part of the entity's greenhouse gas inventory is considered.

Entities can limit reporting to specific activities within their entity boundaries. Small entities can register reductions from specific activities without supplying a complete greenhouse gas inventory if certain criteria are met. Activities within an entity should be individually identifiable at the ground level. The goal of this section of the report is to provide more detailed guidance for: defining boundaries, measuring, monitoring, and estimating changes in carbon stocks, implementing plans to measure and monitor carbon, and developing quality assurance and quality control plans.

Forestry activities mainly affect the exchange of carbon dioxide between the land and atmosphere. Techniques and methods for measuring and monitoring (M&M) terrestrial carbon pools that are based on commonly accepted principles of forest inventory, soil sampling, and ecological surveys are well established and will be elaborated on further in the following sections.

Most forestry activities designed to increase carbon stocks have few non-CO_2 greenhouse gas emissions associated with them. Exceptions include: use of fertilizer to enhance tree growth (possible N_2O emissions), forested wetland restoration (possible increase in CH_4 emissions), use of nitrogen-fixing trees (possible increase in N_2O emissions), and biomass burning for instance in site preparation (possible increase in N_2O and CH_4 emissions). It is likely that these are for the most part insignificant in the forest sector and practical and cost-efficient methods for measuring these non-CO_2 greenhouse gases in this sector are less well developed.

For forestry activities, it is not always necessary to measure all pools (Brown et al., 2000)—selective or partial accounting systems may be appropriate as long as all pools for which emissions are likely to increase as a result of the activity (loss in carbon or emission) are included. The selection of which pools to measure and monitor depends on several factors, including expected rate of change, magnitude and direction of the change, availability and accuracy of methods to quantify change, and cost to measure. All pools that are expected to decrease must be measured and monitored. Pools that are expected to increase by a small amount may not need to be estimated if costs are high relative to the magnitude of the increase. For example, understory herbaceous vegetation in the case of afforestation is rarely a significant factor in the ecosystem carbon budget.

This section focuses on forest ecosystem carbon only, and includes only the carbon pools existing on the land (e.g., live and dead above and below ground biomass and soil; see section 2.1 in the general forest sector guidelines); it does not include methods for wood products that are addressed elsewwhere in this report. Experience has shown that the following steps are needed in any protocol to produce credible and transparent estimates of net changes in carbon stocks:

- Designing a monitoring plan, including delineation of boundaries, stratification of project area, type and number of sample plots, and frequency of monitoring
- Sampling procedures for the carbon stocks
- Methods of estimating the carbon stocks and techniques to analyse the results
- Methods for estimating the net change in carbon stocks
- Development of a quality assurance and quality control plan

The details of how to implement each of these steps and processes are described next. The focus of these guidelines is on field measurements designed to produce accurate net changes in carbon stocks to known levels of precision. A suggested target for the accuracy and precision for forest carbon accounting is to obtain an estimate that is within 10 percent of the true value, with 95 percent confidence that the estimate lies within these bounds.

Entities involved with the forest sector generally have good records on types of management, timber stock, harvest rates, and other information for their different land areas. Such records could be readily used to develop estimates of net changes in carbon stocks from their forest activities (details of approaches are included in section3.2.4). For other entities where such data are not available (e.g. for non-industrial forest land owners), there are a variety of national to regional databases, readily downloadable from the internet, that could be used to estimate changes in carbon stocks on their lands (Box 1). Although using such data are likely to result in less accurate and less precise changes in carbon stocks than estimates based on field measurements, when such data are used in combination with the methods described in this report they can provide, with a modest effort, estimates superior to those based on default values alone. The sources in Box 1 are also useful for verifying that measurements and calculations made by an entity are within the ranges reported at national and regional scales.

Box 1. Internet sites potentially useful for carbon estimation.

Internet site:	*Organization:*	*Relevant content:*
http://fia.fs.fed.us/	USDA Forest Service Forest Inventory and Analysis	-Forest statistics of the U.S. -Forest statistics by state -Sample plot and tree data -Forest inventory methods and basic definitions
http://www.na.fs.fed.us/spfo/fhm/	USDA Forest Service Forest Health Monitoring	-Forest health status -Regional data on soils, CWD -Forest health monitoring methods
http://www.fs.fed.us/ne/global/	USDA Forest Service Global Change Research	-State-by-state forest carbon estimates
http://www.fs.fed.us/ne/durham/4104/products/forcarb.shtml	USDA Forest Service, U.S. carbon budget project	-On-line carbon estimation -Forest carbon estimation methods -U.S. and regional forest carbon statistics
http://www.fs.fed.us/pnw/sev/rpa/	USDA Forest Service resources planning act	-Timber resource statistics and projections
http://unfccc.int/ http://www.ipcc.ch/	United Nations Framework Convention on Climate Change and IPCC	-International guidance on carbon accounting and estimation
http://www.safeclimate.net	World Resources Institute	-Greenhouse gas mitigation projects -Accounting, measuring, and reporting procedures
http://nature.org/initiatives/climatechange/	The Nature Conservancy	-Greenhouse gas mitigation projects -Accounting and reporting procedures
http://www.winrock.org/what/ecosystem.cfm	Winrock International	-Greenhouse gas mitigation projects -Developments in baseline and leakage analyses -Accounting, measuring, and reporting procedures

3.2. Monitoring Design

3.2.1. Boundaries

Forestry activities and the land base for an entity can vary in size (from tens of hectares to up to hundreds of thousands of hectares) and can be confined to a single or several geographic areas. The area may be one contiguous block of land having a single owner or many small blocks of land spread over a wide area having a large number of small or a few large landowners. The spatial boundaries of the land need to be clearly defined to facilitate accurate measuring, monitoring, accounting, and verification. The spatial boundaries can be in the form of permanent boundary markers (e.g., fences), clearly defined topographic descriptions (e.g., rivers/creeks, mountain ridges), spatially explicit located boundaries (identified with a Global Positioning system (GPS)), and/or other methods. Ground-based surveys that delineate property boundaries are an accurate means of documenting land boundaries. There are many different methods and tools that can be employed to identify and delineate land boundaries, including remote sensing (e.g., satellite imageries from optical or radar sensor systems, aerial photos), GPS, topographic maps, and land records. Larger areas across the landscape can be defined through specific boundary descriptions using GPS-based coordinates on topographic maps or other suitable means.

Boundaries need to be properly documented from the start (mapped and described) and should preferably not be subject to any changes through the duration of the estimation period. In the event that boundary changes take place, these would need to be reported and inclusions and/or exclusions of physical land area need to be surveyed using the above described methods (this would mean adjusting the estimated net emissions or removals of greenhouse gases attributable to the activity or entity).

3.2.2. Stratification of land area

Once the land area has been delineated, it is useful to collect basic background information such as land-use history; maps of soil, vegetation, and topography. The land for the project or entity can be geo-referenced and mapped onto a base map. A geographic information system (GIS) would be useful for such an activity. Such maps can then be used to stratify the area into more or less homogeneous units ti increase the efficiency of sampling.

To facilitate the field work and increase the accuracy and precision of measuring and monitoring it is useful to divide the area (population of interest) into sub-populations or strata that form relatively homogenous units. Useful tools for defining strata include ground-truthed maps from satellite imagery (Box 2), aerial photographs, and maps of vegetation, soils or topography. Many of these products are available as GIS data layers (e.g., STATSGO soil maps, USGS Digital Elevation Model, 1992 National Land Cover map) that can be overlain in a GIS to identify possible strata. The key to useful stratification is to ensure that measurements are more alike within each stratum than in the sample frame as a whole. A geographic information system (GIS) can automatically determine stratum size and the size of exclusions or buffer zones.

The size and spatial distribution of the land area does not influence site stratification – one large contiguous block of land or many small parcels are considered the population of interest and are stratified in the same manner. In general, stratification also decreases the costs of monitoring because it is expected to diminish the sampling effort necessary, while maintaining the same level of confidence, because of smaller variation in carbon stocks in each stratum than in the whole area. The stratification should be carried out using criteria that are directly related to the variables to be measured and monitored, e.g. the carbon pools in trees for afforestation. For afforestation, the strata may be defined on the basis of variables such as the tree species(if several), age class (as generated by delay in practical planting schedules), initial vegetation (e.g. completely cleared versus cleared with patches or scattered trees), and site factors (soil type, elevation, and slope etc.). There is, however, a trade-off between the number of strata and sampling intensity. The strata should be large enough to enable adequate sampling within each stratum, but not so large as to incur higher costs. There is no hard and fast rule, and forestry analysts need to use their expert judgment in deciding on the number of strata to include.

Site visits to the entity area and nearby areas with existing vegetation that will be the target of the activity will aid in the stratification of the area. Field assessments and measurements of key variables such as general soil type, topography, and nearby existing vegetation all greatly aid in the stratification of the area and contribute to a cost efficient monitoring plan.

Box 2. Remote sensing data

Remote sensing data are useful for a variety of tasks involved with designing and implementing measuring and monitoring plans for forest-based carbon activities, including: provision of a land-use map for the area, stratification of the area, land-use history, monitoring overall performance, and providing a verifiable record that the carbon pool exists. Below is a table of selected data sets, both public and private, that can gather data for most forestry activities. These sensors have been rigorously calibrated to ensure accurate measurements.

Selected high resolution data sources for monitoring carbon sequestration projects

Sensor/ Satellite	Spatial Resolution	Spectral Resolution	Revisit Time	Owner	Data
Landsat 5 TM	30 m	VNIR/SWIR	16 days	NASA/USGS	http://edc.usgs.gov
Landsat 7 ETM+	30 m	VNIR/SWIR	17 days	NASA/USGS	http://edc.usgs.gov
EO-1 ALI	30 m	VNIR/SWIR	18 days	NASA	http://edc.usgs.gov
EO-1 Hyperion	30 m	VNIR/SWIR	19 days	NASA	http://edc.usgs.gov
IKONOS	1- 4 m	VNIR/SWIR	2 – 5 days	Space Imaging	http://www.spaceimaging.com
Quickbird	0.6 – 3 m	VNIR/SWIR	1 – 4 days	DigitalGlobe	http://www.digitalglobe.com

TM = Thematic Mapper; ETM+ = Enhanced Thematic Mapper Plus; ALI = Advanced Land Imager;
VNIR = Visible to Near Infrared; SWIR = Shortwave Infrared

3.2.3. Type and number of sampling plots

3.2.3.1. Plot type

For forestry activities, permanent or temporary sampling plots could be used for sampling over time to estimate changes in the relevant carbon pools. Both methods have advantages and disadvantages. Permanent sample plots are generally regarded as statistically more efficient in estimating changes in forest carbon stocks than temporary plots because there is high covariance between observations at successive sampling events (Avery and Burkhart, 1983). Moreover, permanent plots permit efficient verification, if needed, at relatively low cost: a verifying organization can find and measure permanent plots at random to verify, in quantitative terms, the design and implementation of the carbon monitoring plan. Disadvantages of permanent plots are that their location could be known and they could be treated differently (such as fertilize, irrigate, etc. to enhance the carbon stocks), and that they could be destroyed or lost by disturbances over the measurement interval. The advantages of temporary plots is that they may be established more cost-efficiently to estimate the carbon stocks of the relevant pools, their location changes at each sampling interval, and they would not be lost by disturbances. The main disadvantage of temporary plots is related to the precision in estimating the change in forest carbon stocks. Because individual trees are not tracked (see Clark et al. 2001 for further discussion), the co-variance term is non-existent and it will be more difficult to attain the targeted precision level without measuring more plots. Thus any time advantage gained by using temporary over permanent forest plots may be lost by the need to install more temporary plots to achieve the targeted precision.

If permanent sample plots are used, marking or mapping the trees to measure the growth of individuals at each time interval is recommended so that growth of survivors, mortality, and ingrowth of new trees can be tracked. Changes in carbon stocks for each tree are then estimated and summed per plot. Statistical analyses are then performed on net carbon accumulation per plot, including ingrowth and losses due to mortality. It is noted here that the USFS has modified its FIA plots to be permanent, fixed radius plots. Because the permanent plots also track mortality, they can be used to track the major changes in dead wood (both lying and standing) after the initial inventory of this component.

3.2.3.2. Number of plots

The level of precision required for a carbon inventory has a direct effect on inventory costs and needs to be carefully chosen by those who will use the inventory results. As mentioned above, from past experience with forest carbon measurement of projects (e.g. Brown 2002), a reasonable estimate of the net change in carbon stocks that can be achieved at a reasonable cost is to within 10% of the true value of the mean at the 95% confidence level.

Once the level of precision has been decided upon, sample sizes must be determined for each stratum in the project area. Each carbon pool may have a different variance (amount of variation around the mean). However, experience has shown that focusing on the variance of the tree component for forestry activities captures most of the variance. Although the variance in other pools may be high they often are a small contribution to the net change in carbon stocks or can actually decrease the total variance when the net change in all pools is estimated. For example, understory in forests can be quite variable but it is generally a very small component of the net change, while dead wood, though highly variable, often reduces the overall variability of the net change in carbon.

The sample size for monitoring in each stratum needs to be calculated on the basis of the estimated variance of the carbon stock in each stratum and the proportional area of the stratum. Typically, to estimate the number of plots needed for monitoring, at a given confidence level, it is necessary to first obtain an estimate of the expected variance of the carbon stock in trees in each stratum. This can be accomplished either from existing data of the type of activity to be implemented (e.g., a forest inventory in an area representative of the proposed activity—see e.g. Box 3) or by making measurements on an existing area representing the proposed activity. For example, if the activity is to afforest agricultural lands and the activity will last for 20 years, then a measure of the carbon stocks in the trees of about 10-15 plots (for plot dimensions see below) of an existing 20 year forest would suffice. If the project area comprises more than one stratum, then this procedure needs to be repeated for each one. Such measurements will provide estimates of the variance in each stratum and with the area of the stratum, the total number of plots per stratum can be estimated using standard statistical methods (see (MacDicken 1997; available at http://www.winrock.org/what/ecosystem_pubs.cfm).

As sampling plots cannot always be relocated or reoccupied for a variety of reasons (e.g., plot markers are overgrown or are removed by people, plots are burned or records are lost), it is prudent to increase the number of plots beyond the minimum in the initial sampling design. By increasing the number of plots to some percentage over the calculated minimum number of samples, there is a cushion that helps to meet the minimum precision requirements even though there are missing plots in subsequent inventories. It is recommended that the minimum sample size be increased by 10 to 15% to allow for plots that cannot be relocated.

Entities that contemplate progressive plantings over time must develop an open-ended monitoring framework that can accommodate the progressive addition of plantings to the area over time. This can be done by predicting the eventual size of the area at year X and progressively assigning distinct stand-age cohorts to separate strata within the overall, and growing, population, anticipating a full contingent of permanent sample plots to be installed by year X. It is recommended that no more than two or three age classes be combined into one cohort class.

Unlike sampling for trees as described above, the same soil sample cannot be monitored over time. Instead, on each sample collection, the unit sampled (soil sample) is destroyed for the analysis of its relevant components, and as variability among samples is high even at small spatial scales, the statistical concept of paired samples, even if collected only centimeters apart, cannot be reliably employed. Thus the changes in mean soil carbon between two temporally-separated sample pools are best quantified by comparing means, via the Reliable Minimum Estimate (RME) approach (Dawkins, 1957), or by directly calculating the difference between the means and associated confidence limits (Sokal and Rohlf, 1995). The objective is not to establish that the two means are significantly different, but rather to estimate with 95% confidence the minimum change in mean soil carbon that has taken place from one monitoring event to the next. For the RME approach (Figure 1), the monitoring results from plots are pooled to derive a mean for the sample population at time “two”, then the 95% confidence interval is subtracted to establish a minimum estimate of the population mean. Change in soil carbon is calculated by subtracting the maximum estimate of the population mean at time “one” (mean at time 1 plus 95% C.I.) from the minimum mean estimate at time “two”. The resulting difference represents, with 95% confidence, the minimum change in mean soil carbon from time “one” to time “two” (Figure 1).

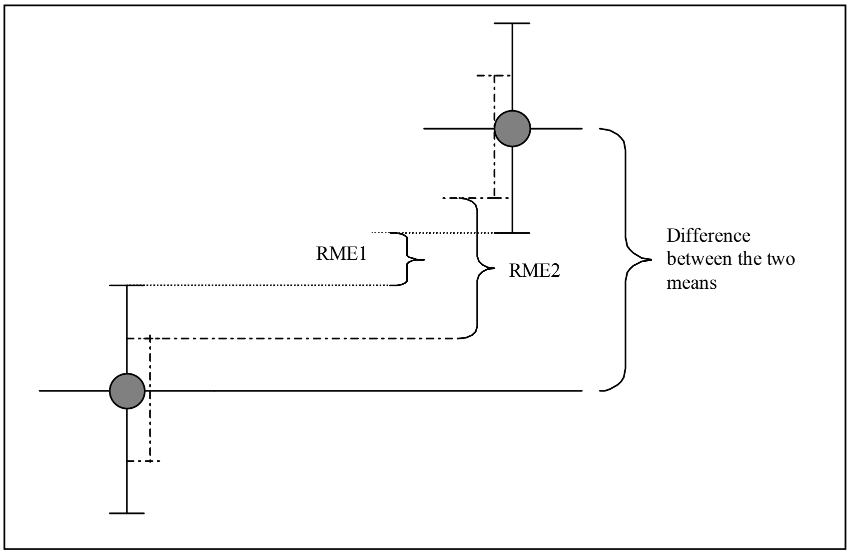


Figure 1. Illustration of the relationship between the magnitude of the reliable minimum estimate (RME) between Time 1 and Time 2 sampling periods and the 95% confidence interval (the solid and dashed bars) around the mean soil carbon content (shaded circle). The confidence interval is a function of the standard error, which equals the standard deviation divided by the square root of the sample size. The larger the sample size the smaller the standard error and the smaller the 95% confidence interval. Thus, RME1 is smaller than RME2 because it is based on fewer samples.

This approach of course assumes normality, and soil carbon values are usually normally distributed. In cases where a data set is shown to be non-normally distributed, for example, where a number of extreme values positively skew the data, data can be transformed (e.g. converting values to logarithms), or alternatively dividing up the non-normally distributed data set *a posteriori* into normally-distributed subsets (i.e. post stratification). Otherwise, a non-parametric test (e.g. Kruskal-Wallis), using the median to represent central tendency, may be applied to quantify differences between sample means.

Box 3: Using FIA Data to Estimate Coefficient of Variation and Number of Sampling Plots

- Download data and apply biomass equations and expansion factors (see section 4.1) for the specific area and forest type of interest. Sum to give plot level results.
- Take means across the dataset or optionally across strata of interest, then calculate standard deviation and the coefficient of variation.
- The minimum number of plots required for monitoring is calculated by solving for n in the formula for the confidence interval (CI). Target ±7-8 % of the mean as a reasonable level of error (this gives the sampling error only; sources of error such as measurement error and model error are likely to account for between 10-20% of total error, thus a target of ±7-8% CI of the mean for sampling will result in a total error for the confidence interval of about 10% of the mean).

  $$n = (s \times 1.960)/(\text{mean} \times 0.08)^2 \qquad \text{(where s = standard deviation)}$$

  The 95 % CI becomes the ±8 % error chosen as a reasonable measurement error level—we can be 95 % sure that the true mean is covered by the determined measurement error.
- If the activity is planned to run for 50 – 70 years, use the large FIA size class (one method of sorting the FIA data) where variation and consequently minimum number of plots is low. (Variation is highest in young or small size class plots regardless of whether regeneration was natural or artificial).
- Minimum number of plots may be decreased by stratification of study area according to, for example, slope, soil type, or site index.

Coefficients of variation and minimum number of sampling plots at 95 % confidence level calculated for specific forest types in three regions using FIA data

Region	*Forest Type*	FIA Size Class	C.V. %	*Number of plots* 95 %
Ohio	Oak-Hickory	*Large*	*27*	*45*
		Medium	*33*	*65*
		Small	*63*	*237*
Illinois	Oak-Hickory	*Large*	*41*	*99*
		Medium	*35*	*74*
		Small	*74*	*325*
Lower Mississippi Valley	Bottomlands	*Large*	*29*	*50*
		Medium	*33*	*66*
		Small	*80*	*384*

How much of the change in mean soil carbon can be reliably reported will depend on the resolution permitted by the monitoring framework. Sampling intensity (i.e. number of soil samples) and frequency must be taken into consideration when attempting to resolve changes in soil carbon over time. Resolution in quantifying the minimum change between two means with a given level of confidence can be expressed as the percent of the absolute difference between the means. A targeted resolution (e.g. 80% of the absolute difference between the means), or alternatively, a targeted magnitude of change in soil carbon (not to exceed the absolute difference between the mean estimates), can be achieved by adjusting sampling intensity, sampling frequency, or a combination of both.

Increasing sampling intensity serves to reduce standard error around mean estimates separated in time, and better distinguish change that takes place (Figure 2). As high levels of variability in carbon among sample units are typical of soils (often ~ 30% C.V.), high sampling intensity is consequently required to discern change.

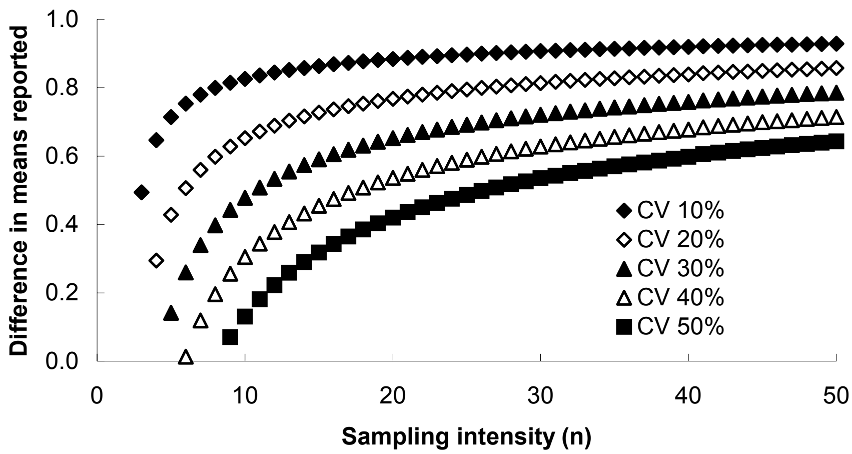


Figure 2. Percent difference in means reported as a function of sampling intensity (with 95% confidence).

The resolution of change detection also depends on the magnitude of the change itself, and as this is time dependent, it is appropriate to consider frequency of sampling. Increasing the interval between sampling events should increase the magnitude of the change that takes place, which, where variance around the means is constant, increases the percentage and magnitude of the change resolved (Figure 3). This is an important consideration, in that small changes expected with short sampling intervals may be undetectable, even with high sampling intensity.

Required sample size (for a targeted % absolute difference between the means or targeted magnitude of change) is thus a function of (1) inherent variability (which can be mitigated for via stratification or reduced by composite sampling), (2) magnitude of change expected (thus sampling interval and assumed rate of soil C accumulation), and (3) desired confidence level. Sample size can be estimated by adapting the commonly used Minimum Detectable Difference calculation (Zar, 1996) to solve for sample size for a targeted difference in means, once a sample interval has been chosen.

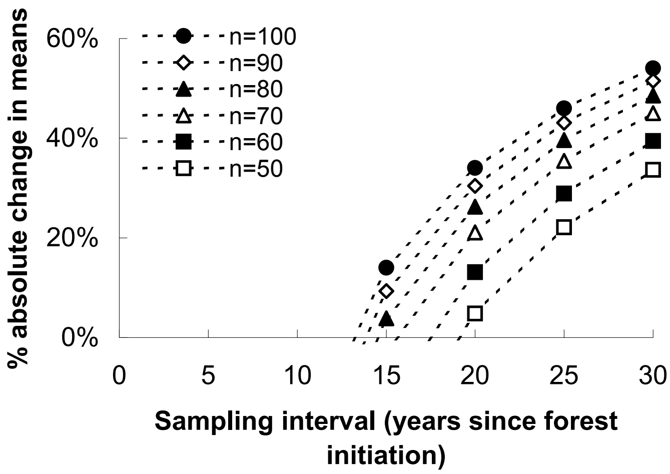


Figure 3. An example of how the percent absolute change in mean (with 95% confidence) soil carbon for afforestation activities varies in relation to the sampling interval and sample size (n), assuming constant coefficient of variation (30%), constant rate of soil carbon accumulation of 0.5 t C/ha.yr, and initial soil carbon 50 t/ha.

3.2.4. Frequency of monitoring

The frequency of monitoring is related to the rate and magnitude of change - the smaller the expected change, the greater the potential that frequent monitoring will not detect a significant change. That is, frequency of monitoring should be determined by the magnitude of expected change—less frequent monitoring is applicable if only small changes are expected.

The frequency of monitoring should take into consideration the carbon dynamics of the activity and costs involved. Given the dynamics of forest processes, they are generally measured over periods of 5-year intervals (e.g., the US National Forest Inventory). For carbon pools that respond more slowly such as soil, even longer periods could be used (see section 4.4). Thus it is recommended that for carbon accumulating in the trees, the frequency of measuring and monitoring should be defined in accordance with the rate of change of the carbon stock, and in the case of plantations in accordance with the rotation length.

Monitoring only the changes in carbon stocks in the permanent monitoring plots does not necessarily provide information that the activity is accomplishing the same changes in carbon stocks across the whole area and that the activity is accomplishing what it set out to do—e.g. plant several thousand hectares of trees. Repeated visits to the carbon monitoring plots will only show that the carbon in those plots (which were randomly located and purportedly represent the population) is accumulating carbon with known accuracy and precision. To give confidence that the overall activity is performing as well as the plots, it is also suggested that, through time, periodic checks are made to ensure that the overall activity is performing the same way as the plots. This can be accomplished through field checking using indicators of carbon stock changes such as tree height for afforestation activities. Thus entities could produce such indicators that can readily be field-checked across the area. High resolution remote sensing imagery could also be used to accomplish this task, at least with respect to area treated. Periodic acquisition of such imagery or even aerial imagery could be a relatively inexpensive way to monitor overall performance.

3.3. Sampling Design

3.3.1. Plot layout

Permanent plot locations can be selected either randomly or systematically. If stratified random sampling is used, sample units for each stratum can still be selected systematically. If little is known about the population being sampled, random selection of sample units is generally safer than systematic selection, however this would depend on the area and type of activity. If plot values are distributed irregularly in a random pattern, then both approaches are about equally precise. If some parts of the strata have higher carbon content than others, systematic selection will usually result in greater precision than random selection.

For some areas, it may not be possible to pre-stratify because from all the usual characteristics, the site appears to be homogeneous. However, it is possible that after the first monitoring event, for example, the change in carbon stocks is highly variable and that on further analysis the measurements can be grouped into like classes—in other words can be post-stratified.

3.3.2. Size and shape of sample plots

The size and shape of the sample plots is a trade-off between accuracy, precision, and time (cost) of measurement. Experience has shown that sample plots containing smaller sub-units of various shapes and sizes, depending on the variables to be measured are cost efficient. For instance, for afforestation, all trees are measured in the entire sample plot, whereas non-tree vegetation, litter and soil data are collected in a smaller area known as a sub-plot. The FIA standard plot is comprised of a cluster of four subplots of relatively small radius. The monitoring system could use this design or a series of nested plots as described next.

Nested plots for recording discrete size classes of stems and/or select forest components are a practical design for sampling and are better suited to stands with a wide range of tree diameters or to stands with changing diameters and stem densities that take place over time than are fixed-area plots (Figure 4). Optimum area for nested plots can be anticipated by predicting changes in stem density and mean stem diameter over time, or by direct measurements of proxy stands of known age. It is likely that individual trees in even age stands will grow at different rates resulting in *uneven size* distribution, and trees will occur in all nested plots in later years of measurements. However, when the forest is likely to remain *evenly sized,* a single plot would suffice.

Nested plots are composed of several (typically 2 to 4, depending upon forest structure) full circular plots and each of the nested circles should be viewed separately. When trees attain the minimum size for one of the nested circles they are measured and included, and when they exceed the maximum size, measurement of that tree in that nest stops and begins in the next larger nest. If ingrowth into a new nest occurs between censuses the growth up to the maximum size is included with the smaller nest, and growth in excess of this size is accounted in the larger nest (see Box 4 in section 3.4.1.1).

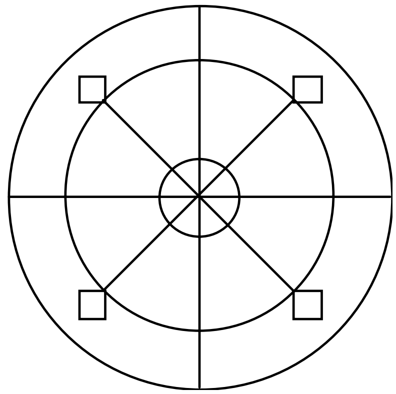


Figure 4. Schematic diagram of nested, fixed area circular sample plots. Saplings could be measured in the smallest circular plot (about 1 m radius), trees between 2.5 and 50 cm diameter at breast height (dbh) could be measured in the medium circular plot (about 10 to 14 m radius depending on stem density), trees above 50 cm dbh could be measured in the largest circular plot (about 20 m radius), and understory and fine litter could be measured in the four small plots located in each quadrant of the sample area. The radius and diameter limits for each circular plot would be a function of local conditions and expected size of the trees through time.

Plots are extrapolated to full hectare area to produce carbon stock estimates. Extrapolation by use of expansion factors occurs by calculating the proportion of a hectare that is occupied by a given plot. As an example, if a series of nested circles measuring 4 m, 14 m and 20 m in radius were used, their areas are equal to 50 m^2, 616 m^2 and 1,257 m^2 respectively. The expansion factors for converting the plot data to a hectare basis are 198.9 for the smallest, 16.2 for the intermediate and 8.0 for the largest nested circular plot.

Time and effort spent in field measurement depends both on sample size (number of plots) and plot area. While increasing sample size increases precision, increasing plot area decreases variability between samples roughly following the relationship derived by Freese (1962) (see Table 1),

$$\mathbf{CV_2^2 = CV_1^2 * \sqrt{(P_1 / P_2)}}$$

where "CV" is the coefficient of variation and "P" is plot area. Thus, by increasing plot area, variation between plots is reduced, which allows for a smaller sample size while achieving the same precision level. For example, pilot studies could provide an estimate of the CV and plot area (e. g. from FIA plots-see Box 3.), then a CV could be selected to achieve the desired precision and cost considerations. Substitution of these values into the above equation will provide an estimate of the plot area needed for optimum sampling.

Table 1. Effect of plot area on inter-plot variability and range of values (min/max)

Statistics	0.04 ha. plot	1 ha. plot
n=	75	3
Mean (t C/ha)	209	209
Variance	*22754*	*5870*
SD	*151*	*77*
SE	17	44
C.V. (%)	*72*	*37*
95% CI (t C/ha)	34	176
MIN	*48*	*155*
MAX	*799*	*297*

3.3.3. Selection of carbon pools to measure and monitor

The selection of which pools to measure and monitor depends on several factors, including expected rate of change, magnitude and direction of the change, availability and accuracy of methods to quantify change, and cost to measure. All pools that are expected to decrease as a result of activities must be measured and monitored. Pools that are expected to increase by a small amount relative to the overall rate of change need not be measured and monitored, for example, understory herbaceous vegetation in the case of an afforestation project. The decision matrix shown in Table 2 presents the main carbon pools for forests (see Ch. 3 for definitions of these pools) and which ones should (Y), maybe (M), or should not (N) be measured for each forestry activity type.

Clearly it makes sense to measure and monitor the carbon pool in live trees and their roots for all activity types. Aboveground non tree or understory may need measuring if this is a significant component such as where shrubs are present in large numbers; it may not need measuring if the understory is dominated by herbaceous material as this is likely to account for very small changes over the duration of the activity (less than three percent). It is recommended that forest floor be measured in most activity types, especially where the forest is likely to be dominated by conifers, as this can be a significant component of the total carbon pool. Dead wood is composed of standing dead trees and downed dead wood. For changes in management for timber, this must be measured as often this pool decreases —e.g., from more intensive harvesting to less intensive harvesting will cause the dead wood pool to decrease (less timber is removed and less slash is left behind). Soil organic carbon is likely to change significantly for afforestation, forest restoration, and mineland reclamation activities as the initial condition of soil is likely to be low. However changes in forest management or even forest preservation (from harvesting to preservation) are likely to produce very small to no changes in soil carbon and the cost to measure this pool could exceed the value of the carbon. The decision to monitor wood products depends on whether the site will ultimately be harvested or not. For short rotation biomass energy plantations this would be necessary as the product is the main purpose of the activity. Activities related to changes in forest management need also to measure and monitor wood products as often this reduces the change in the live carbon pool; likewise for forest preservation if the original activity was a timber production forest. In other words, all the live biomass "protected" by the activity (either as preservation or reduced logging intensity) cannot be claimed as a savings for the atmosphere because some of the biomass went into long-term wood products.

Table 2. A decision matrix to illustrate the selection of pools to measure and monitor in forestry projects (modified from Brown et al. 2000). For explanation of letters and numbers in this table, see below

Activity type	Carbon pools to be measured and monitored						
	Living biomass			Dead Organic Matter		Soil	Wood Products[1]
	Aboveground: trees	Aboveground: non-tree	Below-ground	Forest floor	Dead wood		
Afforestation	Y1	M2	Y3	M4	M5	Y6	M
Forest restoration	Y1	M2	Y3	M4	M5	Y6	N
Forest management	Y1	N	Y3	M4	Y5	N	Y
Agroforestry	Y1	M2	Y3	M4	N	Y6	M
Short rotation biomass energy plantations	Y1	N	Y3	M4	N	Y6	Y
Mineland reclamation	Y1	M2	Y3	M4	M5	Y6	M
Forest preservation	Y1	M2	Y3	M4	M5	M6	Y

[1] No methods are provided for measuring this pool as the focus of this report is on ecosystem carbon; see case study 5.6.2 for methods for estimating change in stocks of wood products

Letters in the above table refer to the need for measuring and monitoring the carbon pools:

Y= Yes - the change in this pool is likely to be large and should be measured.
N = No - the change is likely small to none and thus it is not necessary to measure this pool.
M = Maybe - the change in this pool may need to be measured depending upon the forest type and/or management intensity of the project.

Numbers in the above table refer to different methods for measuring and monitoring the carbon pools:

1= See methods of carbon stock measurement for aboveground biomass of trees (Section 4.1.1)
2 = See methods described for aboveground biomass of non-trees vegetation (Section 4.1.2)
3 = See methods for measuring/estimating the carbon stock in belowground biomass (Section 4.2).

4 = See methods for measuring the carbon stock in forest floor (4.3.1)
5 = See methods for measuring dead wood (Section 4.3.2).
6 = See methods for measuring the carbon pool in soils (Section 4.4).

3.4. Measurement and Data Analysis Techniques

Measurements of net carbon flows for forests generally lend themselves to the stock change method—that is the amount of carbon sequestered is estimated as the net change in carbon stocks over a period of time (see Ch. 3 above for more discussion of stock versus flow methods). Much of the discussion in section 3.0 above focuses on the design needed to precisely estimate changes in carbon stocks. Although for most components the stock change method is applicable, for some components the flow method may be appropriate. For example, changes in the dead wood pool are often estimated from the difference between inputs from slash (estimated from the difference between total tree biomass and mass of timber removed) and outputs from decomposition of the dead wood. In the next sections, methods for both the stock and flow approach, when appropriate, are presented for estimating the change in carbon stocks.

Methods are based on measurements and models resulting in estimates of biomass, except for soil, which can be measured in units of carbon directly. Biomass is generally converted to units of carbon by multiplying biomass by 0.5, unless more specific data are available.

3.4.1. Living aboveground biomass

3.4.1.1. Trees

The carbon stocks of trees are most accurately and precisely estimated through the use of direct methods, i.e. through a field inventory, where all the trees in the sample plots above a minimum diameter are measured. The minimum diameter is often 5 cm at dbh, but can vary depending on the expected size of trees —for arid environments where trees grow slowly, the minimum diameter may be as small as 2.5 cm diameter, whereas for humid environments where trees grow rapidly it could be up to 10 cm diameter. Biomass and carbon stock are estimated using appropriate allometric equations applied to the tree measurements. For practical purposes, tree biomass is often estimated from equations that relate biomass to dbh only. Although the combination of dbh and height as the independent variable is often superior to dbh alone, measuring tree height can be time consuming and will increase the expense of any monitoring program. Furthermore, the empirical database of trees in the US shows that highly significant biomass regression equations can be developed with very high r-squares using just dbh (see Tables 3 and 4).

Often biomass equations are reported for individual species or groups of species, but this literature is sometimes inconsistent and incomplete for all tree species in the United States. However, it has been shown by recent analyses that equations based on multi-species groupings can work well for US forests (Schroeder et al. 1997).

Jenkins et al. (2003) compiled all available diameter-based allometric regression equations for estimating total aboveground and component biomass, defined in dry mass terms, for trees in the United States. A total of 318 biomass equations were assembled for over 100 species from 104 sources (Jenkins et al. 2003). Jenkins et al. used a method to generate “pseudodata” (Pastor et al.

1984) by calculating biomass values for a range of diameters within bounds of raw data for each equation. These pseudodata were used to refit new equations for 10 broad species groups (Table 3; details of the species in each of the 10 groups can be found in Jenkins et al. 2003).

When using allometric equations, the given maximum diameter used in the regression should be carefully observed. Using the equations for trees that exceed the maximum diameters should only be done after careful consideration of the functional form of the equation. In particular, caution should be used with equations that are based on an exponential function (e.g. the equations in Table 3). Equations using a more sigmoidal form, where biomass is constrained at large diameters, are more stable and can be more safely used even beyond the given maximum bounds (Brown et al. 1989). Table 4 lists the general equations of Schroeder et al. (1997) and Brown and Schroeder (1999) which have this sigmoidal/constrained form. Figure 4 compares the estimated biomass per tree for a given diameter based on the exponential and sigmoidal models. Up to about 75 cm diameter the models give the same estimated biomass per tree but beyond this point the exponential models result in an increasingly larger and larger estimated biomass whereas the sigmoidal model is more conservative.

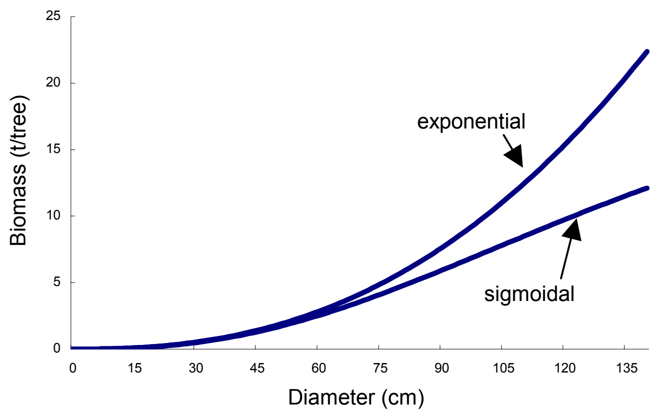


Figure 4. A comparison of the relative treatment of large trees by equations with an exponential form (e.g. the hard maple/oak/hickory/beech equation; Table 3) and those with a limiting function (e.g. the eastern hardwoods equation; Table 4).

In addition the equations of Jenkins et al. (2003), while an exhaustive coverage of the US tree flora, are dominated by western species in the softwood category. Western softwoods are unique with regard to stature and consequently do not well represent southern pines or eastern fir-spruce species. In contrast the equations for pines and fir-spruce of Brown and Schroeder (1999, Table 4) are calculated specifically for these groups of species. An example of how to calculate aboveground tree biomass for a plot using allometric regression equations is given in Box 4.

Table 3. Parameters and equations[1] for estimating total aboveground biomass for hardwood and softwood species, grouped into 10 main classes, in the U.S.

	Species Group	Parameters β_0	β_1	Data points[2]	Max[3] dbh (cm)	RMSE[4] (log units)	R^2
Hardwood	Aspen/alder/ cottonwood/ willow	-2.2094	2.3867	230	70	0.507441	0.953
	Soft maple/birch	-1.9123	2.3651	316	66	0.491685	0.958
	Mixed hardwood	-2.4800	2.4835	289	56	0.360458	0.980
	Hard maple/oak/ hickory/ beech	-2.0127	2.4342	485	73	0.236483	0.988
Softwood	Cedar/larch	-2.0336	2.2592	196	250	0.294574	0.981
	Douglas-fir	-2.2304	2.4435	165	210	0.218712	0.992
	True fir/hemlock	-2.5384	2.4814	395	230	0.182329	0.992
	Pine	-2.5356	2.4349	331	180	0.253781	0.987
	Spruce	-2.0773	2.3323	212	250	0.250424	0.988
Woodland[5]	Juniper/oak/mesquite	-0.7152	1.7029	61	78	0.384331	0.938

[1]Biomass equation:

$$y = \mathrm{Exp}\,(\beta_0 + \beta_1 \ln x)$$

where

y = total aboveground biomass (kg) for trees 2.5-cm *dbh* and larger

x = diameter at breast height (cm)

Exp = "e" to the power of

ln = natural log base "e" (2.718282)

[2]Number of data points generated from published equations (generally at 5-cm *dbh* intervals) for parameter estimation.

[3]Maximum *dbh* of trees measured in published equations.

[4]Root mean squared error or estimate of the standard deviation of the regression error term in natural log units.

[5]Woodland group includes both hardwood and softwood species from dryland forests.

Table 4. Parameters and equations[1] for estimating aboveground biomass for southern and eastern hardwood and softwood species in the U.S. (from Brown and Schroeder 1999).

Class	Parameters β_0	β_1	β_2	β_3	Data Points	Max *dbh* cm	R^2
Hardwoods	0.5	25000	2.5	246872	454	85.1	0.990
Pines	0.887	10486	2.84	376907	137	56.1	0.980
Fir-spruce	0.357	34185	2.47	425676	83	71.6	0.980

[1]Biomass equation:

$$y = \beta_0 + \frac{\beta_1 x^{\beta_2}}{x^{\beta_2} + \beta_3}$$

where

y = aboveground biomass (kg)

x = diameter at breast height (cm)

An example of how to calculate aboveground tree biomass and its change using a nested plot design and using allometric regression equations is given below in Box 4.

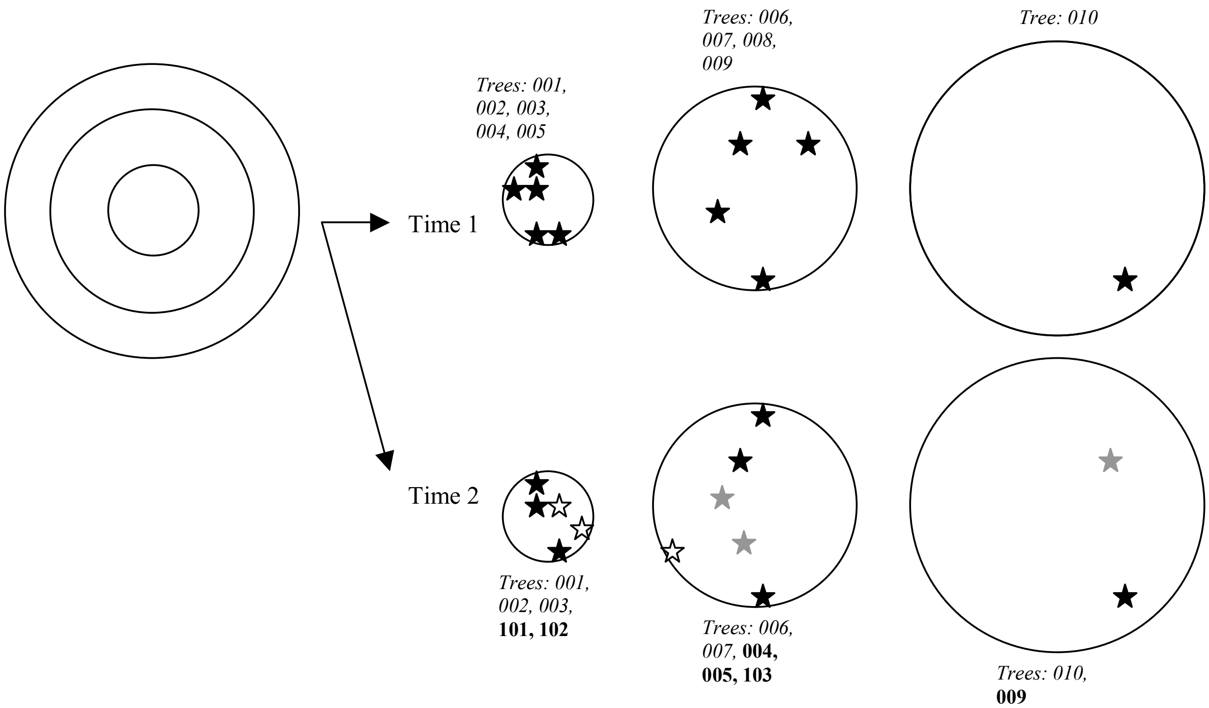
Box 4. Calculating the carbon stock and its change in aboveground trees from allometric regression equations

As a hypothetical example, a single plot from oak/hickory forest will be examined. The plot consists of three nested subplots:

- 5 m radius for trees measuring 2.5 to < 10 cm dbh
- 14 m radius for trees ≥ 10 to < 50 cm dbh
- 20 m radius for trees ≥ 50 cm dbh

The allometric regression equation of Jenkins et al. (2003) is used for hard maple/oak/hickory/beech to convert from diameter at breast height (dbh) to biomass.

The figure and table below show measurements over two time periods. Note the following: at time 2, ingrowth of trees too small to be measured at time 1 (trees 101 and 102 in the small nest and 103 in the intermediate nest) and outgrowth from one plot size and ingrowth into the next size when the max/min thresholds are passed (trees 004, 005 small to intermediate, tree 009 intermediate to large).



The three nested plots at time 1 and time 2. The stars indicate the position of trees. At time 2, black stars indicate trees that remained in the same size class as at time 1. Grey stars indicate trees that have grown into the next class and white stars are trees that have exceeded the measurement minimum for that plot for the first time.

Time 1 Tag	Nest	dbh (cm)	Biomass (kg)	Time 2 Tag	Nest	dbh (cm)	Biomass (kg)
001	Small	2.6	1.37	001	Small	3.1	2.10
002	Small	5.3	7.74	002	Small	5.8	9.64
003	Small	6.1	10.90	003	Small	6.8	14.20
004	Small	6.2	11.34	004	Intermediate	10	36.32
005	Small	8.1	21.74	005	Intermediate	12.1	57.76
006	Intermediate	10.2	38.11	006	Intermediate	10.9	44.79
007	Intermediate	12.3	60.11	007	Intermediate	13.3	72.71
008	Intermediate	38.6	972.67	008	DEAD	DEAD	972.67
009	Intermediate	48.2	1670.20	009	Large	51	1916.30
010	Large	57.0	2512.15	010	Large	58	2620.79
				101	Small	2.5	1.24
				102	Small	2.8	1.64
				103	Intermediate	10.3	39.03

Change in biomass stocks in each subplot =
(Σ biom. increments of trees remaining in subplot size class) +
(Σ biom. increments for outgrowth trees [= Σ max biomass for size class – biomass at time 1]) +
(Σ biom. increments for ingrowth trees [= Σ biomass at time 2 – min biomass for size class])

Small subplot = [(2.1-1.37) + (9.64-7.74) + (14.20-10.9)] + [(36.32-11.74) + (36.32-21.74)] + [(1.24-1.24) + (1.64-1.24)]

= (0.73 + 1.90 + 3.30) + (24.97 + 14.57) + (0 + 0.39) = 45.87 kg

Intermediate subplot = [(44.79-38.11) + (72.71-60.11)] + [(1826.12-1670.20)] + [(36.32-36.32) + (57.76-36.32) + (39.03-36.32)]

= (6.68 + 12.60) + (155.92) + (0 + 21.44 + 2.71) = 199.35 kg

Large subplot = ((2620.79-2512.15)) + ((-)) + ((1916.30-1826.12))

= (108.64) + (-) + (90.18) = 198.82 kg

Change in biomass = Σ Δbiomass in each subplot x expansion factor for that subplot

Small - 45.87 x 127.32 = 5840.50 kg/ha
Int. - 199.35 x 16.24 = 3237.44 kg/ha
Large - 198.82 x 7.96 = 1582.13 kg/ha

Sum = 10660.07 kg/ha = 10.7 t/ha for the time interval

An alternative approach for estimating biomass of forests is to base it on the volume of the commercial component of the tree. The volume of the commercial component is estimated using standard techniques in forestry. This method is commonly used with temporary plots. The estimated volume then needs to be converted to total aboveground biomass, including the other tree components, such as branches, twigs, and leaves. This volume-based method is based on factors developed at the stand level, for closed canopy forests, and cannot be used for estimating biomass of individual trees.

There are two potential methods. The first calculates biomass directly from stand volume for different vegetation types in different regions, and the second has the additional step of calculating a biomass expansion factor (BEF) but the equation can be broadly applied to three vegetation types across the United States. In both cases, growing stock volume (GSV)is defined as the net outside bark volume of growing-stock trees at least 12.5 cm in diameter to a minimum of 10 cm diameter at tree top or at the point where the central stem breaks into limbs (definition used by the USFS when it does its forest inventory in the FIA plots). Other definitions of volume could be used but the but the BEFs reported here could *not* be applied—new ones would have to developed for local conditions.

1. Direct Method – Smith, Heath and Jenkins 2003

Smith et al. (2003) used growing stock volume data from the FIA and the biomass equations of Jenkins et al. (2003) to develop regression equations of the form:

$$\boxed{\text{Aboveground biomass (t/ha)} = F \times (G + (1-\exp(-GSV\ (m^3/ha)\ /H))}$$

Where

GSV = growing stock volume
F, G, H = regression coefficients

A total of 57 variants of this equation were developed for a variety of forest types across 10 regions in the continental US. Details of the coefficients for each of the variants of the equation can be found in Smith et al. (2003; the manuscript can be downloaded from the internet: http://www.fs.fed.us/ne/newtown_square/publications/technical_reports/index.shtml).

2. Biomass Expansion Factor Method – Schroeder et al. 1997, Brown and Schroeder 1999.

This method is expressed as (Brown and Schroeder, 1999):

Aboveground biomass (t/ha) = GSV (m^3/ha) x BEF (t/m^3)
Where:
GSV = growing stock volume
BEF = [total aboveground biomass of all living trees to a minimum diameter at breast height of 2.5 cm]/[growing stock volume]

The BEF is significantly related to the GSV for most forest types, generally starting high at low volumes then declining at an exponential rate to a constant low value at high volumes. Thus using one value for the BEF for all values of GSV is incorrect. This general relationship has been found to apply to many forests of the world, including tropical forests (Brown 1997) and forests in China (Fang et al. 1998)

Schroeder et al. (1997) and Brown and Schroeder (1999) provide methods to calculate the BEF (t/m^3) for all forest types and regions across the eastern US.

Hardwoods:	BEF = exp(1.912 – (0.344 x ln GSV))	
	If GSV > 200 m^3/ha use a constant BEF of 1.	
Spruce-Fir:	BEF = exp(1.771 - (0.339 x ln GSV))	
	If GSV > 160 m^3/ha use a constant BEF of 1.	
Pines:	GSV < 10 m^3/ha	BEF = 1.68 t/m^3
	GSV 10 – 100 m^3/ha	BEF = 0.95 t/m^3
	GSV > 100 m^3/ha	BEF = 0.81 t/m^3

Where GSV = growing stock volume in m^3/ha.

An example of using both the direct and the BEF methods to calculate biomass for two forest types is found in Box 5. The two methods differ by less than 5 % for both forest types and thus can be considered as giving equivalent results. Thus, the user may select either method.

Box 5. Calculating biomass from stand volume data

Example 1: An oak-hickory forest in Wisconsin with a growing stock volume of 180 m^3/ha.

A. Direct Method

Smith et al. (2003) list the following coefficients for calculating aboveground biomass (AGB) of oak-hickory in the Northern Lake States:

F = 307.5 G = 0.0748 H = 186.9

Therefore AGB = F x (G + (1 – exp(-volume/H)))
= 307.5 x (0.0748 + (1 – exp(-180/186.9)))
= 213.1 t/ha

B. BEF Method

As growing stock volume is < 200 m^3/ha we must calculate the BEF. Oak-hickory is a hardwood forest type.

Therefore BEF = exp(1.912 – (0.344 x ln GSV))
= exp(1.912 – (0.344 x ln(180)))
= 1.134

Therefore AGB = GSV x BEF
= 180 x 1.134
= 204.1 t/ha

Example 2: A loblolly pine plantation in Georgia with a growing stock volume of 120 m^3/ha.

A. Direct Method

Smith et al. (2003) list the following coefficients for calculating aboveground biomass (AGB) of planted pine in the South East States:

F = 187.3 G = 0.0662 H = 184.9

Therefore AGB = F x (G + (1 – exp(-volume/H)))
= 187.3 x (0.0662 + (1 – exp(-120/184.9)))
= 101.8 t/ha

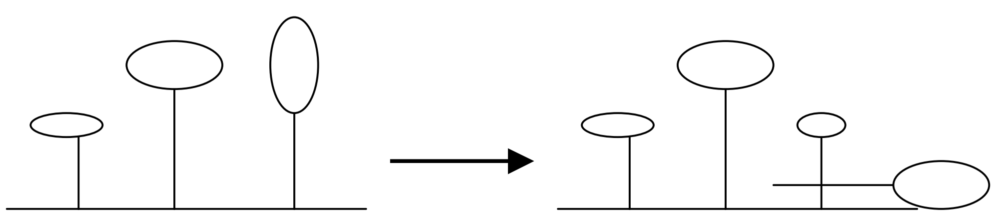
B. BEF Method

As growing stock volume is > 100 m^3/ha and the forest type is pine the BEF is 0.81 t/m^3.

Therefore AGB = GSV x BEF
= 180 x 0.81
= 97.2 t/ha

An important consideration is the accounting of ingrowth and mortality when estimating change in biomass stocks. Not understanding where, when and how to include these components can lead to erroneous estimates of changes in aboveground biomass. The approach taken depends on whether permanent or temporary plots are being used. For permanent plots, the method is based on tracking individual surviving trees (see Box 4) while for temporary plots the estimation is of the pool of biomass at time 1 and time 2. For permanent plots there is no requirement to track tree mortality but there must be an estimate of trees growing into the plots (i.e. exceeding the minimum measurement size only at time 2). For an accurate estimate using temporary plots both ingrowth and mortality should be included but due to the nature of temporary plots it is normally not possible to determine the date of a mortality event or which trees had passed the minimum measurement boundary during the census interval.

Figure 5 shows a hypothetical example of the same trees being measured with the temporary plot and the permanent plot method (almost invariably temporary plots would be in different locations at time 1 and time 2 but for ease of illustration the exact location is remeasured). The change in biomass stock for ingrowth trees is the biomass of the new tree at time 2 minus the minimum biomass required for a tree to be measured.



Time:		t_1			t_2	
AGB:	10	12	13	12	15.2	7

Permanent Plot:
Stand Increment = (Σ Increments of surviving trees) + (Σ Increment(s) of ingrowth)
= ((12 - 10) + (15.2 - 12)) + (7 - 4)
= (2 + 3.2) + (3)
= 8.2

Temporary Plot:

Stand Increment = (ΣAGB at t_2 - ΣAGB at t_1)
= ((12 + 15.2 + 7) – (10 + 12 + 13))
= (34.2 – 35)
= - 0.8

Figure 5. An illustration of the methods of calculating change in aboveground biomass stocks for permanent plots and temporary plots. AGB = aboveground biomass of live trees; AGB of a minimum-sized tree is set arbitrarily to 4 units (based on Clark et al. 2001).

It is clear that the two methods give widely different results. Although in this example the temporary plot gives a negative change in stock, it could just as readily give a larger positive change than the permanent plots. For example, estimates of changes in biomass stocks based on temporary forest plots in Bolivia were 214 % higher than those in permanent plots in recently logged forest and 361 % higher in unlogged forest (Winrock International, 2004, unpublished data).

3.4.1.2. Non-tree vegetation

Herbaceous plants in forest understory can be measured by simple harvesting techniques in small subplots (2-4 per plot are recommended) within each sample plot (Figure 4). A small frame (either circular or square), usually encompassing about 0.25 m^2 can be used. The material inside the frame is cut to ground level, pooled by plot, and weighed. Well-mixed sub-samples are then oven-dried to determine dry-to-wet mass ratios. These ratios are then used to convert the entire sample to oven-dry mass.

For shrubs and other large non-tree vegetation it is desirable to measure the biomass by simple destructive harvesting techniques. A small sub-plot (dependent on the size of the vegetation) is established and all the shrub vegetation is harvested and weighed. An alternative approach, if the shrubs are large, is to develop local shrub biomass regression equations based on variables such as crown area and height or diameter at base of plant or some other relevant variable (e.g., number of stems in multi-stemmed shrubs). The equations would then be based on regressions of biomass of the shrub versus some logical combination of the independent variables.

3.4.2. Belowground biomass

The measurement of aboveground biomass is relatively established and simple. Belowground biomass (coarse and fine roots), however, can only be measured with time-consuming methods. Consequently it is more efficient and effective to apply a regression model to determine belowground biomass from knowledge of aboveground biomass. The following regression models can be used to estimate belowground biomass or (Cairns et al., 1997):

Boreal:
$$BBD\ (t/ha) = \exp(-1.0587 + 0.8836 \times \ln ABD + 0.1874)$$

Temperate:
$$BBD = \exp(-1.0587 + 0.8836 \times \ln ABD + 0.2840)$$

Tropical:
$$BBD = \exp(-1.0587 + 0.8836 \times \ln ABD)$$

Where BBD = belowground biomass density in tons per hectare (t/ha) and ABD = aboveground biomass density (t/ha)

$n = 151$; $r^2 = 0.84$

Applying these equations allows an accurate assessment of belowground biomass. This is the most practical and cost-effective method of determining biomass of roots.

For the calculation of increment the exact usage of these equations is important. For tagged trees in permanent plots, it is not possible to simply calculate the total aboveground biomass at time 1 and time 2, apply the equations and then divide by the number of years. This approach cannot account for ingrowth or mortality trees (see section 4.1). Instead change in belowground biomass stocks should be calculated using the following method:

1. Calculate aboveground biomass at time 1 using allometric equations and the appropriate expansion factors.
2. Calculate increment of biomass accumulation aboveground between time 1 and time 2 (see section 4.1), and add to time one to estimate the biomass stock at time 2.
3. Apply appropriate belowground equation (above) to estimate belowground biomass at each time interval.
4. (Time 2 belowground – time 1 belowground) / number of years = annual change in stock of biomass belowground.

3.4.3. Dead organic matter

3.4.3.1. Forest floor

The forest floor (see Ch. 3 for definition) can be directly sampled by simple harvesting techniques in small subplots within each permanent plot (Figure4). A small frame (either circular or square), usually encompassing an area of about 0.25 m^2 (if the forest floor is particularly deep as often found in some of the western US forests, then a smaller frame [0.06 m^2] can be used), as described for herbaceous vegetation above, is generally used. If herbaceous material is collected, the forest floor can be collected from the same frames at the same locations. Using a pair of clippers, all live vegetation from the sample area is carefully removed. Living mosses should be clipped at the base of the green, photosynthetic material. Using a sharp knife or a pair of clippers, the forest floor along the inner surface of the frame is carefully cut through to separate it from the surrounding soil. The entire volume of the forest floor must be carefully removed from within the confines of the sampling frame down to the top of the mineral soil layer (to distinguish the bottom of the forest floor from the top of the mineral soil see below section on soil organic carbon). All litter within the frame is collected, all samples pooled and weighed. A well-mixed sub-sample is collected and placed in a marked bag. This sample is used to determine oven dry-to-wet weight ratios to convert the total wet mass to oven-dry mass. For practical purposes when a laboratory is not available, forest floor samples can be sent to professional labs for drying and weighing.

For the forest floor, amounts of C per unit area are given by:

(forest floor oven dry weight (g) / sampling frame area (cm^2)) x 100

where multiplying by 100 converts the units to metric t/ha.

3.4.3.2. Dead wood

Dead wood, both standing and lying, does not generally correlate well with any index of stand structure (Harmon et al., 1993). Methods have been developed for measuring biomass of dead wood and have been tested in many forest types and generally require no more effort than measuring live trees (Harmon and Sexton, 1996; Delaney et al., 1998). There are two approaches that can be used to estimate the volume of dead wood lying on the ground, depending upon the expected quantity present.

Method 1 –when the quantity is expected to be less than about 10-15% of the aboveground biomass: A time-efficient method is the line-intersect method. Experience has determined that at least 100 m length of line per plot must be used (Harmon and Sexton 1996). For practical field purposes experience has shown that placing two 50 m sections of line at right angles across the plot center is a time efficient approach. However, the line could just as readily be established as one 100 m length through the plot center. To allow remeasurement of the same 'dead wood plot' it is important to accurately record where the line was placed. Each piece of dead wood is classified into one of several density classes. The diameters of all pieces of wood that intersect the line are measured, their density class noted, and the volume per unit area calculated for each density class as follows:

Volume of lying dead wood
Volume (m^3/ha) $=\pi^2 * [(d1^2 + d2^2 \ldots\ldots dn^2)/8L]$

Where d1, d2, dn = diameter, in cm, of each of the n pieces intersecting the line, and L = the length of the line (100 m recommended) (for more details see Harmon and Sexton, 1996).

Method 2 –when the quantity is expected to be more than 10-15% of the aboveground biomass: When the quantity of dead wood lying on the forest floor is expected to be high and variably distributed, it is more desirable to do a complete inventory of the wood in the permanent plots. In this method all the dead wood in one of the medium circles of the sample plots should be measured (see also Harmon and Sexton 1996 for details on the methods). For a complete census, the volume of each piece of dead wood lying within the circle is calculated based on the diameter measurements taken at 1 m intervals along each piece of dead wood in the plot. The volume of each piece is then estimated as the volume of a truncated cylinder based on the average of the two diameter measurements and the distance between them (usually 1 m). As with method 1, each piece of dead wood is also classified into a density class. The volume is summed for each density class and using the appropriate factor (based on the area of the plot) expressed on a m^3/ha basis for each density class.

Density measurements: Experience shows that three density classes are sufficient—sound, intermediate and rotten. An objective and consistent way to distinguish between them is needed. A common practice in the field is to strike the wood with a strong sharp blade--if the blade bounces off it is sound, if it enters slightly it is intermediate, and if it causes the wood to fall apart it is rotten. Samples of dead wood in each density class are then collected to determine their wood density. Mass of dead wood is then the product of volume per density class (from above equation) and the wood density for that class. Thus a key step in this method is classifying the dead wood into its correct density class and then adequately sampling a sufficient number of logs in each class to represent the wood densities present. It is advisable to sample at least 10 logs or more of each different density class. In forests with unique plant forms, like early successional species and palms as in tropical forests, it is also advisable to treat these as separate groups and sample them the same way as well.

The simplest method to estimate dead wood density would be to have a value for the proportion of undecomposed density that each of the three decomposition classes represents. Undecomposed wood densities area widely available in the literature (e.g. forestry handbooks). This initial density value multiplied by the decomposition proportion by the volume gives biomass. Heath and Chojnacky (2001) calculated the proportions as 90 % (sound), 70 % (intermediate) and 40 % (rotten) for forests in the northeast USA. These proportions could be used, but test samples to check the validity of these default data would be very important.

For forest areas with few species and where the rate of decomposition of wood is well known for given species or forest types, simple decomposition models could be locally developed for estimating the density of the dead wood at different stages of decomposition (Beets et al. 1999). Volume of wood would still need to be estimated based on either method 1 or 2 above, but the density could be estimated based on the model of decomposition.

Rates of decomposition across regions and forest types are given (Table 6). Where the age of a piece of dead wood is known, current density can be calculated from decomposition rate, then the biomass can be calculated from volume.

An example of a dead wood calculation is given in Box 6.

Box 6. Calculating biomass density of dead wood.

In the following example dead wood is sampled along 100 m of line (line-intersect method) to determine the biomass stock. Diameters and density classes are recorded and a sub-sample collected to determine density in each of the three density classes (sound, intermediate and rotten). The following numbers represent the hypothetical results:

13.8	cm	sound
10.7	cm	sound
18.2	cm	sound
10.2	cm	intermediate
11.9	cm	intermediate
56.0	cm	rotten

Densities of subsamples: Sound: 0.43 t/m^3
Intermediate: 0.34 t/m^3
Rotten: 0.19 t/m^3

Volume of sound wood: $\pi^2 \times [d1^2 + d2^2 \ldots\ldots dn^2/8L]$
$\pi^2 \times [13.8^2 + 10.7^2 + 18.2^2/800]$
7.85 m^3/ha

Volume of intermediate wood: $\pi^2 \times [10.2^2 + 11.9^2/800]$
3.03 m^3/ha

Volume of rotten wood: $\pi^2 \times [56.0^2/800]$
38.7 m^3/ha

Biomass stock = (7.85 x 0.43) + (3.03 + 0.34) + (38.7 x 0.19) = 11.8 t/ha

Standing dead wood can be measured as part of the tree inventory. Standing dead trees should be measured according to the same criteria as live trees. However, the measurements that are taken and the data that are recorded vary slightly from live trees. For example, if the standing dead tree contains branches and twigs and resembles a live tree (except for leaves) this would be indicated on the field data records. From the measurement of its dbh, its biomass can be estimated using the appropriate biomass regression equation as for live trees, subtracting out the biomass of leaves (about 2-3 % of aboveground biomass). However, a dead tree can contain only small and large branches, or only large branches, or no branches – these conditions need to be recorded in the field measurements. Branches need to be classified in proportion to the size of the standing dead tree so that the total biomass can be reduced accordingly to account for less of the dead tree remaining. When a tree has no branches and is just the bole, then its volume can be estimated from measurements of its basal diameter, height, and an estimate of its top diameter;

and its biomass can be estimated with its density class. Examples of how to estimate the biomass of standing dead wood are given in Box 7.

Box 7. Calculating biomass of standing dead wood.

1. A tree with no leaves in mixed hardwood forest with a diameter of 25 cm at breast height, density class assumed to be sound.

Use the equation of Jenkins et al. (2003) for mixed hardwood forests, 3 % deduction due to the lack of any leaves.

y = exp (–2.4800 + 2.4835 x ln(25)) = 248.16 kg x 0.97 = 240.72 kg

As this dead tree is the only dead tree measured in a 14 m plot the mass is multiplied by the expansion factor of 16.24 to give a biomass of 3.91 t/ha.

2. A sugar maple tree with missing branches (missing branches estimated as 15 % of aboveground biomass). Diameter at breast height measured as 51 cm; density class assumed to be sound.

Use the equation of Jenkins et al. (2003) for hard maple/oak/hickory/beech with a 15 % deduction for missing biomass.

y = exp (–2.0127 + 2.4342 x ln(51)) = 1,916.3 * 0.85 = 1,628.9 kg

As this dead tree is the only dead tree measured in a 20 m plot the mass is multiplied by the expansion factor of 7.96 to give a biomass density of 12.97 t/ha.

3. A bole with no branches is measured. The height is 15 m, basal diameter is 40 cm and top diameter is 25 cm. Analysis of a cored sample reveals a wood density of 0.49 g/cm^3.

The volume of a truncated cone $= 1/3\pi \times h \times (r_1^2 + r_2^2 + r_1 \times r_2)$

$= 1/3\pi \times 1500 \times (20^2 + 12.5^2 + 20 \times 12.5)$

Biomass density $= 1{,}266{,}455\ cm^3 \times 0.49\ g/cm^3$

$= 620{,}563$ g = 0.62 tons

As this dead tree is the only dead tree measured in a 14 m plot the mass is multiplied by the expansion factor of 16.24 to give a biomass density of 10.08 t/ha.

Table 6: Decomposition rate constants and half-lives for down dead wood by region and forest type.

Region	Forest Type	Decomposition Rate[a]	Half Life
		Year^{-1}	*Years*
Pacific Northwest	Douglas-fir	0.022	31.5
	Spruce-fir	0.028	24.8
	Hemlock-spruce	0.031	22.4
	Lodgepole pine	0.041	16.9
	Hardwoods	0.082	8.5
	Ponderosa pine	0.017	40.8
	Redwoods	0.014	49.5
Rocky Mountains	Douglas-fir	0.022	31.5
	Ponderosa pine	0.017	40.8
	Spruce-fir	0.014	49.5
	Larch	0.022	31.5
	Lodgepole pine	0.023	30.1
South	Oak-hickory	0.075	9.2
	Oak-pine	0.060	11.6
	Bottomland hardwood	0.112	6.2
	Natural pine	0.056	12.4
	Planted pine	0.056	12.4
Northeast	White/red pine	0.042	16.5
	Spruce-fir	0.042	16.5
	Oak-hickory	0.075	9.2
	Maple-beech-birch	0.062	11.2
North Central	White/red pine	0.042	16.5
	Spruce-fir	0.042	16.5
	Maple-beech	0.082	8.5
	Aspen-birch	0.082	8.5
	Bottomland hardwood	0.112	6.2
	Oak-hickory	0.060	11.6

[a]from Turner et al. 1993

3.4.4. Soil organic carbon

To obtain an accurate inventory of organic carbon stocks in the mineral soil or organic soil (see Ch. 3 for definitions), three types of variables must be measured: soil depth, soil bulk density (calculated from the oven-dry weight of soil from a known volume of sampled material), and the concentrations of organic carbon within the sample. General guidance on sampling and analyzing forest and agricultural soils for estimating carbon stocks can be found in Lal et al. (2001) and Robertson et al. (1999).

Tracking changes in soil carbon over time requires that the same *equivalent* mass of soil is measured from one monitoring event to another. Sampling to a fixed depth (equal volumes) can result in underestimation of carbon gains via forestation because as the bulk density generally decreases over time, the same sampled volume contains less of the original soil mass equivalent. Rates of accrual estimated from sampling to a fixed depth should therefore be considered *conservative* estimates of soil carbon accretion.

Sampling to greater depth, in cases where there are no additions of new carbon at greater depth, reduces the detectability of change by diluting additions that take place in the upper layers of the soil column. Richter et al. (1999), monitoring 35 years of forest regrowth of loblolly pine in the Calhoun Experimental Forest in South Carolina, found no significant increase in soil carbon below 7.5 cm depth. Likewise, Markewitz et al. (2002), contrasting formerly cultivated and never-tilled sites under longleaf pine, found the most notable carbon difference in the upper 10 cm of soil. As hardwood leaf litter is likely to break down and become incorporated into the soil more quickly, and hardwood trees typically produce more roots than pines, inputs of soil carbon are expected to a greater depth, to 40 or 50 centimeters (MacDonald, 1999, Winrock, unpublished data, Figure 6).

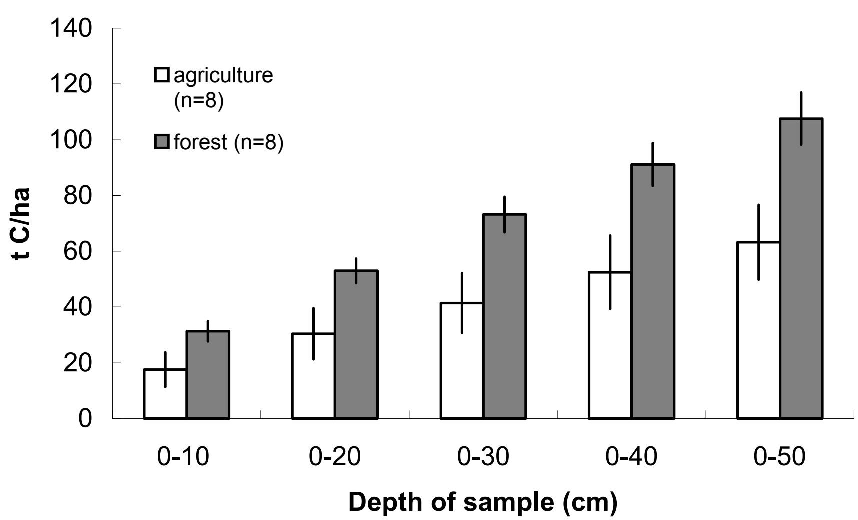


Figure 6. Mineral soil carbon, forest = 50-70 year old bottomland hardwoods on clay soil, bars = 95% confidence intervals (data from ongoing projects monitored by Winrock staff—unpublished data).

The forest floor is sampled as described above, exposing the top of the mineral or organic soil. In some soils, telling the difference between the bottom of the forest floor and the top of the mineral soil can be difficult. In those cases, one can refer to standard soil sampling methods (e.g. in Robertson et al. 1999) for tips on how to distinguish the top of mineral soil. Coring tools and liners to hold the soil cores of varying lengths are commercially available, but it is often impractical to use the manually-operated impact-driven soil-coring tool below about 30 cm. However, simple soil corers have been found to work in many soils, particularly in the deeper soils of the central and southern regions of the US. Shallow soil pits to 30 cm or so also work well and have been shown to be a cost-efficient method. The impact-driven soil coring tool is not very practical for collecting deep cores, and it is not practical nor cost efficient to use a truck or trailer-mounted hydraulically-driven soil coring tool in most forest areas.

Composite sampling is an effective means to reduce inter-sample variability. This is done by aggregating a pre-determined number of samples (2-4 samples) from each collection site in the field, from which one sample is derived for analysis. The resulting *composite* sample captures more of the range of inter-microsite variability in soil carbon.

3.4.4.1. Sampling the mineral soil

Soil chemical concentrations are generally measured in air-dried soils, while bulk density measurements must be made on oven-dried soils. It is often easiest to take separate sets of cores for the bulk density and carbon determination because the sample preparation for each differs somewhat. In addition, fewer cores may be needed to accurately estimate bulk density because it is generally less variable than soil chemical properties.

Using the core sampler method, mineral soil samples are collected from within the area of the sampling frame after the forest floor has been removed. Because the carbon concentration of forest floor materials is much higher than that of the mineral soil, including even a small amount of surface organic material can result in a serious overestimation of soil carbon stocks.

Once the soil corer has been inserted into the soil to the desired depth, it must be removed from the ground by pulling upwards in a smooth vertical motion. The top and bottom (or bottom only depending upon the coring tool used) of the core should be trimmed even with the rims. When taking cores for measurements of bulk density, care should be taken to avoid any loss of soil from the cores; if any material is lost the sample needs to be taken again. All the material in the corer should be placed into an appropriately labeled sample bags.

The excavation method involves digging a small pit, wide enough to collect the soil to the depth desired. A hand shovel can be used to collect material to the desired depth, making sure that sufficient volume of soil from the sides of the pit equal approximately the volume of a soil corer. It is important that material is collected from the entire depth to avoid biasing the sample. Uniform rings can be used to sample sides of the pit for bulk density, making sure not to compress the soil

As with forest floor samples, soil samples can also be sent to a professional lab for analysis. Experience shows that commercial laboratories exist throughout the country and routinely analyze plant and soil samples for a variety of measures using standard techniques. It is recommended that the selected laboratory be checked to make sure that they follow the commonly accepted standard procedures both with respect to sample preparation (sieving etc.), drying temperatures, and method for carbon analysis (dry combustion method).

For bulk density determination, dry the samples in an oven at 105 ^{o}C for a minimum of 48 hours. And if the soil contains coarse rocky fragments, retain the coarse fragments, weighed them and record their weights.

For soil carbon determination, the material is sieved through a 2 mm sieve and the material is then thoroughly mixed. The dry combustion method using a controlled-temperature furnace (e.g. LECO CHN-2000 or equivalent) is the recommended method for determining total carbon in the soil (Nelson and Sommers 1996). Where carbonate minerals may be present, a new dry combustion method using the LECO RC-412 multi-carbon analyzer is the preferred method. Both organic and inorganic forms of carbon can be measured on the same mineral soil sample in one analytical run. An alternative is to remove any carbonates through acid treatment before hand.

As an alternative to the multi-carbon analyzer, the dichromate oxidation method with heating is acceptable for measuring organic C (Nelson and Sommers 1996) and the pressure calcimeter method is acceptable for determining soil carbonates (Sherrod et al. 2002). The classic Walkley-Black method is not acceptable for determining organic C in soil because of incomplete wet combustion and other inaccuracies. Additional details about the multi-carbon analyzer and other carbon analysis methods can be found in the FIA Lab Methods Manual (Amacher et al. 2003).

The bulk density of the mineral soil core is calculated by:

$$\rho_b = \frac{ODW}{CV - (RF / PD)}$$

Where:

ρ_b = Bulk density of the < 2mm fraction, in grams per cubic centimeter (g/cm^3)
ODW = Oven dry mass of fine fraction (<2 mm) in grams
CV = Core volume in cm^3
RF = Mass of coarse fragments (> 2 mm) in grams
PD = Density of rock fragments in g/cm^3. This is often given as 2.65 g/cm^3, though the actual value may be determined by submerging a known mass of coarse fragments in a known volume of water; the displacement gives an estimate of rock volume, which can then be used to calculate density.

The bulk density and carbon concentration data are used to compute amounts of carbon per unit area.

For the mineral soil, amounts of C per unit area are given by:

$$C\ (t / ha) = [(soil\ bulk\ density, (g / cm^3) \times soil\ depth\ (cm) \times \%\, C)\ ] \times 100$$

In this equation the %C must be expressed as a decimal fraction; e.g. 2.2 %C is expressed as 0.022 in the equation. An example of how to calculate carbon in organic soil carbon plots is given in Box 8.

Box 8. Calculating mass of soil carbon per unit area

Mass of carbon per unit volume is calculated by multiplying carbon concentration (reported as percent mass) times bulk density (g/cm^3). Bulk density equals the oven dry weight of the soil core divided by the core volume. For example, a core of volume 94.2 cm^3 (1 cm radius x 30 cm length cylinder) with dry weight 144.06 yields a bulk density of 1.53 g/cm^3. Referencing the sample depth, mass per unit area is calculated, which represents a corresponding volume of soil. Thus,

$$\text{Volume/hectare} = 100\text{ m} \times 100\text{ m} \times 0.3\text{ m (sample depth)} = 3 \times 10^9\text{ cm}^3 = 3{,}000\text{ m}^3$$

$$\text{Mass/hectare} = 3 \times 10^9\text{ cm}^3 \times 1.53\text{ g/cm}^3\text{ (bulk density)} = 4.586 \times 10^9\text{ g} = 4{,}586\text{ tons}$$

Part of this volume is of course occupied by tree roots, which are accounted for separately, however, this fraction tends to be insignificant and for practical purposes is ignored here.

From within the same plot, the corresponding aggregate core analyzed for carbon concentration yields 0.8 % mass carbon. Mass per unit area, 4,586 t/ha, calculated previously, multiplied times 0.8 % yields equivalent 36.7 tons of soil carbon per hectare. A series of sample calculations of mass soil carbon are tabulated below.

Sample weight (g)	Volume (cm^3)	Bulk density (g/cm^3)	Volume/ha (m^3)	Mass/ha (tons)	Carbon conc. (% mass)	Mass soil C (t/ha)
144.06	94.2	1.53	3.E+09	4586	0.80	36.7
126.48	94.2	1.34	3.E+09	4026	0.82	33.0
146.95	94.2	1.56	3.E+09	4678	0.72	33.7
132.20	94.2	1.40	3.E+09	4208	0.90	37.9
147.39	94.2	1.56	3.E+09	4692	0.53	24.9
131.96	94.2	1.40	3.E+09	4200	1.39	58.4
115.95	94.2	1.23	3.E+09	3691	1.22	45.0
133.96	94.2	1.42	3.E+09	4264	1.09	46.5
115.59	94.2	1.23	3.E+09	3679	1.20	44.2
139.03	94.2	1.48	3.E+09	4425	0.76	33.6
					Mean	39.4
					95 % CI	6.7

3.4.5. Non-CO_2 gases

Although the primary purpose of forestry activities is to increase carbon stocks, forestry activities may also result in changes in non-CO_2 greenhouse gas emissions and removals. Such activities include biomass burning; application of synthetic and organic fertilizers to soils; cultivation of nitrogen fixing trees; and peat flooding and drainage. In addition, land-use activities that disturb soils, e.g., site preparation during afforestation, may affect non-CO_2 emissions and removals from soils. For many cases, changes in non-CO_2 greenhouse gas emissions or removals caused by these activities will be small relative to net changes in carbon stocks over the lifetime of the activity. No guidelines are provided in this document for monitoring, estimating, or reporting significant fluxes of non-CO_2 gases for forestry.

3.5. Estimation Methods and Uncertainty

3.5.1. Estimating net change for the system

The type of activity influences how each of the carbon stock components are integrated into an estimate of the net change in carbon stock at each monitoring interval. The activities listed in Table 2 can be grouped into two main classes. The first class includes those that would typically be implemented on non-forested lands (afforestation, forest restoration, agroforestry, short-rotation biomass energy plantations and mineland reclamations). The other class includes those activities implemented on existing forested land (forest management and forest preservation). This grouping has implications for how measurements and estimations are integrated to arrive at an estimate of the net change in total carbon stocks in the time interval.

3.5.1.1. Activities on non-forested lands

All activities on non-forested lands typically begin on land that initially has very low carbon stocks in vegetation (generally less than a couple of tons/ha) and variable amounts in the soil. In each of these cases a sampling regime would be implemented that monitors each of the carbon stock components indicated in Table 2. These methods have already been discussed above in sections 4. The task is then how to combine all the estimates of the carbon stock for each component to arrive at an estimate of the net change in total carbon.

Using permanent plots, the carbon stock for living and standing dead trees above- and belowground and down dead wood of individual plots can be monitored through time and therefore the change in carbon stocks can be estimated directly at the plot level. In this case the change in carbon stocks for the different components should be summed within plots to give a per plot carbon stock change in t C/ha. The plot level results are then averaged to give mean and 95 % confidence intervals. The mean change in carbon stocks per unit area is then multiplied by the area of the activity to produce an estimate of the total change in carbon. If stratification is used, this approach is repeated for each stratum and then all strata are added together to estimate the total. This total is then converted to t CO_2 equivalent by multiplying by 3.67.

Soils, forest floor and non-tree vegetation are calculated separately as the statistics, number of sampling plots and even the sampling interval may be different than for the other components.

The results from these measurements are analyzed to produce an estimate of the mean and the 95% confidence interval. This estimate is then added to create a system level mean and 95% confidence interval. The total confidence interval is calculated as follows:

$$\text{Total 95\% CI} = \sqrt{([95\%CI_{veg}]^2 + [95\%CI_{soil}]^2 + [95\%CI_{forest\ floor}]^2 + [95\%CI_{non\text{-}tree\ vegetation}]^2)}$$

Where $[95\%CI_{veg}]$ = 95% confidence interval for vegetation, $[95\%CI_{soil}]$ = 95% confidence interval for soil etc.

If part of the afforested area is harvested, the sampling plots would theoretically monitor the change in live and dead biomass. However, they would not monitor the amount going into wood products. As mentioned above, the reason wood products need to be considered is that the decrease in live biomass from harvesting does not mean that the equivalent amount of carbon went into the atmosphere—some of it could go into long-lived wood products. Thus to correctly estimate the effects of harvesting on the net change in carbon stocks, the amount of wood biomass going into long-term wood products is needed (as described in case study 5.6.2). This quantity per unit area and its estimated 95 % confidence interval would then be added to the total change. An example of the integration of all the components from permanent plots is given in Box 9, where the initial carbon stocks are of agricultural crop.

If temporary plots are employed to measure changes in carbon stocks, the mean and 95% confidence interval of the carbon stock in each component across all plots is calculated at time 1 and time 2. The total carbon stock at each time interval is then estimated by summing the means for each component and the total error is estimated as follows:

$$\text{Total 95\% CI} = \sqrt{([95\%CI_{c1}]^2 + [95\%CI_{c2}]^2 + \ldots\ldots\ldots [95\%CI_{cn}]^2)}$$

Where $[95\%CI_{c1}]$ = 95% confidence interval for component 1 (e.g. aboveground biomass), component 2, etc. for all components measured in the plots)

The change in carbon stock is calculated by subtracting the mean carbon stock at time 2 from that at time 1. The confidence interval is calculated as:

$$\text{Total 95\% CI} = \sqrt{([95\%CI_{time1}]^2 + [95\%CI_{time2}]^2)}$$

Where $[95\%CI_{time1}]$ = 95% confidence interval for time 1 and $[95\%CI_{time2}]$ = 95% confidence interval for time 2.

The net change is calculated as above for permanent plots by subtracting the initial carbon stocks (practically zero if afforestation occurs on former cropland). Finally, the total carbon stock change on a per unit area basis is multiplied by the total area to produce an estimated total change in carbon and confidence interval for the area.

All the discussion in this section has been for an activity with a single stratum. If the activity contained multiple strata then each would be calculated separately as detailed here. Once the area-based carbon dioxide equivalents and confidence were calculated for each strata the numbers could be combined. The new confidence interval for the combined strata would be estimated as follows:

Total 95% CI = $\sqrt{([95\%CI_{s1}]^2 + [95\%CI_{s2}]^2 + \ldots\ldots\ldots [95\%CI_{sn}]^2)}$

Where $[95\%CI_{s1}]$ = 95% confidence interval for strata 1, strata 2, etc. for all strata measured in the project).

Box 9. Calculating net change for the system

The hypothetical example is a afforestation activity on 500 ha of former cropland. The baseline for carbon stocks is cropland with an average carbon stock in vegetation of 0.9 t C/ha. The following table reports the change in carbon stock between years 1 and 10.

Plot number	Change in carbon stocks (t C/ha)			SUM
	Living biomass		Dead Organic Matter	
	Aboveground: trees	Belowground	Dead wood	t C/ha
Plot 1	12.1	2.4	0.1	14.6
Plot 2	11.5	2.3	0.0	13.8
….	…	…	…	…
….	…	…	…	…
Plot 31	12.6	2.5	0.1	15.1
Plot 32	10.9	2.2	0.1	13.2

Mean	13.9
95 % CI	*2.4*
+ Non-tree Vegetation	1.8
N-T V 95 % CI	*0.1*
+ Forest Floor	0.2
F.F. 95 % CI	*0.1*
+ Soil	0.5
Soil 95 % CI	*0.1*
- Baseline stock on cropland	0.9
Baseline 95 % CI	*0.1*
NET change in carbon stock	15.5
95 % CI	*2.4*

Net change in stocks over area: 15.5 t C/ha x 3.67 t CO_2eq/ha / t C/ha x 500 ha
± the 95 % CI: 2.4 t C/ha x 3.67 t CO_2eq/ha / t C/ha x 500 ha

Therefore the net change is: 28,443 ± 4,419 t CO_2eq over 10 years

3.5.1.2. Activities on forested lands

Forest management involves alternating periods of harvest and regrowth, and as such carbon stocks in forest biomass vary over time (Figure 7). In addition, changes in management practices can result in increased carbon storage through a variety of ways, such as: changing the timing or intensity of harvest, reducing damage to the residual stand through more efficient logging practices, switching from clear-cut harvesting to selective-cut harvesting, or by creating or widening riparian buffer zones.

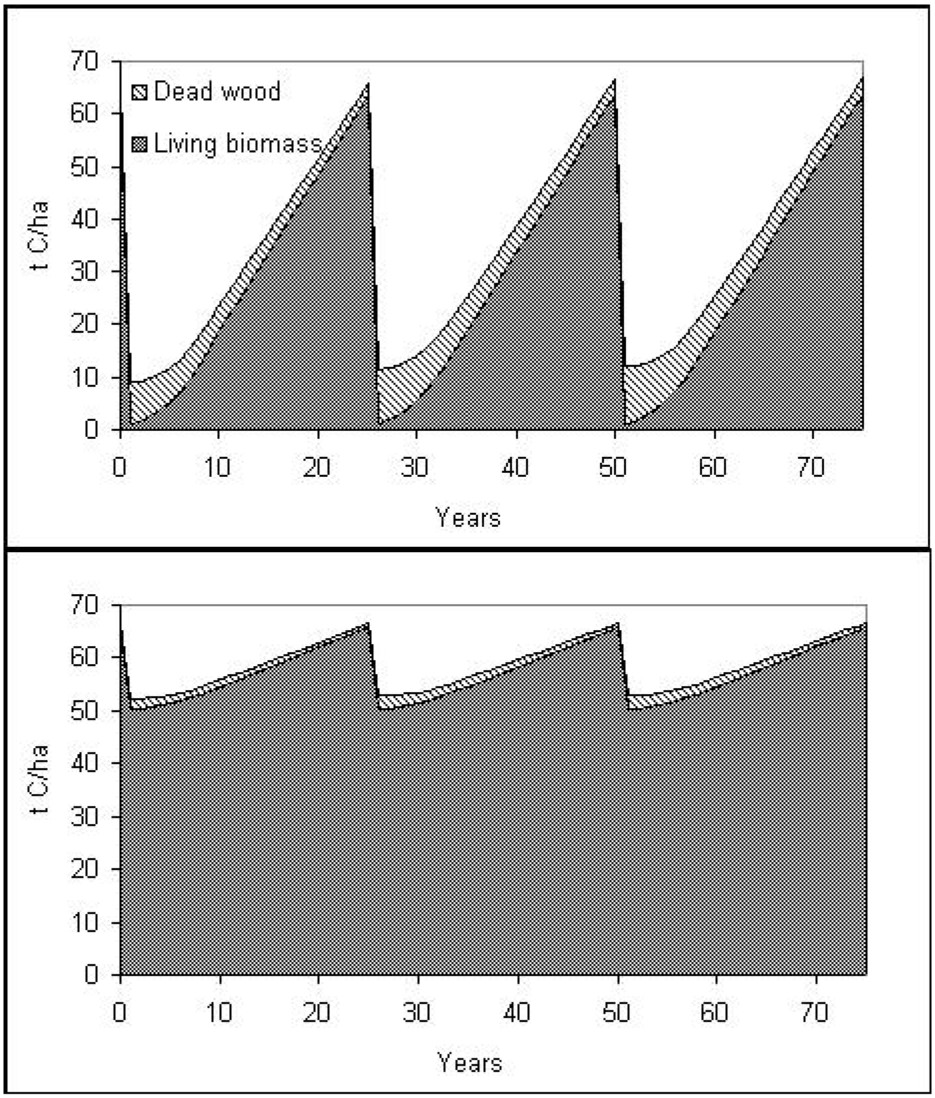


Figure 7. Carbon stocks associated with (top) complete harvest of forest followed by 25-year even-aged management and (bottom) selective harvest of a similar forest.

Initially it is important to consider what carbon pools are important in forest management activities. Clearly live vegetation and dead wood are central. With the examples in Figure 7, the amount of dead wood increases over time with subsequent harvest. The amount of dead wood that accumulates through time is a function of the amount of slash left behind and the rate of decomposition of that slash—the larger the amount of slash and the slower the rate of decomposition, the larger the amount that accumulates. Measurement of soil organic carbon is, at best, marginally beneficial in forest management activities. Soil carbon may be reduced slightly immediately following harvest (Laiho et al, 2002, Carter et al, 2002), however, any losses will be regained as the succeeding forest regrows with accompanying soil organic matter inputs (Carter et al., 2002). Relative difference in post-harvest effects on soil carbon between varying harvest intensities are slight and often undetectable (Carter et al., 2002). Because differences in soil carbon resulting from changes in management are seldom discernible or long-lived, the significant additional effort of soil sampling on projects on forested lands is not recommended.

The differences in the effects of clear-cut versus selective-cut harvests on forest ecosystem carbon stocks (Figure 7) has implications for the accuracy and precision of measuring and monitoring their changes over time. To address this, two alternative methodologies for monitoring changes in carbon stocks are presented here.

Direct Measurement Method

Where the activity includes clear-cut harvesting, the simplest approach is to install sample plots and monitor the changes in carbon stocks. As shown in Figure 7, there will be periods of carbon accumulation and period of carbon loss resulting in positive and negative changes in carbon stocks. With a well-designed sampling regime, remeasurements will reveal shifts of pre-harvest living biomass to the dead wood pool (i.e. logging slash and collateral mortality), and subsequent decomposition over time, as well as regrowth, resulting after harvest. Mean total carbon stocks and 95% confidence intervals are calculated in the same way as for activities on non-forested lands.

Indirect Measurement Method

In situations of selective-cut harvesting, where harvest intensity per hectare is low, the required number of plots to capture the variation in harvested areas could be so large as to make measurement neither financially nor practically feasible. In this case it is possible to use targeted measurements plus the statistics of the relevant logging activity. It is more appropriate to measure the change in live biomass due to harvesting directly. The change in live biomass caused by logging is a result of the extraction of timber and damage to residual trees. The following information is typically required to calculate carbon gains and losses through the indirect measurement method:

- Total volume removed
- Area damaged per cubic meter removed
- Amount of slash and damage to residual stand per volume removed
- Rate of regrowth in the harvested areas
- Decomposition rates of slash.

The change in carbon stocks using this approach is calculated as:

$$\Delta \text{ live biomass C} + \Delta \text{ dead biomass C}$$

where Δ is the change in carbon of live biomass and dead biomass caused by timber harvesting. The estimates of each term can be made annually or over longer time periods.

Δ live biomass C = (rate of C accumulation over the time interval – [biomass C from logging damage + C in timber extracted])

The change in live biomass caused by logging is a result of the extraction of timber, the slash from the harvested tree, and damage to residual trees, all of which will cause a decrease in live biomass or represent a negative quantity after harvest. On the positive side, is the rate of carbon accumulation during regrowth that applies to those areas affected by timber extraction. To estimate the amount of damaged and dead biomass produced in the logging operations involves establishing field plots around a harvested tree(s) (the plot usually has dimensions equivalent to the distance from the stump to the top of the harvested tree and as wide as the crown diameter of the harvested tree), collecting information about the initial diameter and height of the harvested tree, measuring the amount of volume removed, and measuring the diameter of all trees that were severely damaged and presumed to be dead. The number of such plots to establish and sample would be based on the same procedures described above in section 2.3.2. These measurements are then combined to produce a ratio of total amount of live biomass converted to dead biomass per unit mass of timber extracted. The rate of carbon accumulation in the regrowing forest could be obtained from measurements of tagged trees in the sample plot over time as described in section 4.1.1, but only applied to the area affected by the logging (area of the gap).

Δ dead biomass C = (dead biomass from logging damage and slash x decomposition rate)

The slash and damaged wood is assumed to enter the dead wood pool, where it starts to decompose. Each year more dead wood is added from harvesting, but each year some is lost because of decomposition and resulting emissions of carbon. Decomposition of dead wood is modeled as a simple exponential function based on mass of dead wood and a decomposition coefficient (proportion decomposed per year). The decomposition coefficients for a variety of forest types are given in Table 6. The change in carbon stocks of the slash and damaged wood could be measured in the field but it tends to be time consuming and costly and the range of decomposition rates given in Table 6 cover all major forest types in the US. Mean total changes in carbon stocks and 95% confidence intervals could then be calculated in the same way as shown in Box 9.

3.6. Quality Assurance and Quality Control (QA/QC)

Measuring and monitoring requires provisions for quality assurance (QA) and quality control (QC) to be implemented via a QA/QC plan to ensure that the reported carbon units are reliable and meet minimum measurement standards. The plan should become part of the documentation and include procedures for: (1) collecting reliable field measurements; (2) verifying laboratory procedures; (3) verifying data entry and analysis techniques and; (4) data maintenance and archiving.

3.6.1. QA/QC for field measurements

Collecting reliable field measurements is an important step in the quality assurance plan. Those responsible for the carbon measurement work should be fully trained in all aspects of field data collection and data analyses. Experience has shown that it is wise for the entity involved with measuring and monitoring prepare Standard Operating Procedures (SOPs) for each step of the field carbon measurements which should be adhered to at all times. These SOPs should detail all phases of the field measurements so that future personnel can repeat the measurements identically to previous times. It is recommended that a document be produced and filed with the project documents that show that QA/QC steps have been followed.

Field crews should receive extensive training and should be fully cognizant of all procedures and the importance of collecting data as accurately as possible. In addition, an audit program for field measurements and sampling should be established to audit data collection. A typical audit program consists of three types of checks. During a *hot check*, auditors observe field crew members during data collection on a field plot. *Cold checks* occur where the field crews are not present for the audit. Finally *blind checks* represent the complete remeasurement of a plot by the auditors. Hot checks permit the correction of errors in techniques. Measurement variance can be calculated through blind checks. At the end of the fieldwork 10-20 % of the plots should be checked independently. Field data collected at this stage can be compared with the original data. Any errors found should be corrected and recorded. Any errors discovered could be expressed as a percentage of all plots that have been rechecked to provide an estimate of the measurement error.

3.6.2. QA/QC for laboratory measurements

Standard operating procedures (SOPs) should also be prepared by the operating entity and followed for each part of the analyses. Typical steps for the SOP for laboratory measurements include calibration of combustion instruments for measuring total C or C forms using commercially-available certified C standards. Likewise all balances for measuring dry weights should periodically be calibrated against known weights, for fine scale balances this is most accurately carried out by the manufacturer. Where possible 10-20 % of samples could be reanalyzed/reweighed to produce an error estimate. Professional laboratories typically perform these steps, and if such a lab is used such records need to be obtained by the entity.

3.6.3. QA/QC for data entry

To produce reliable carbon estimates, the proper entry of data into the data analyses spreadsheets is required (this step may be redundant if the field data are collected in an electronic format). It is important that steps are taken to ensure that errors are minimized. Common sense should be used when reviewing the results of the data analysis to make sure that they fit within the realm of reality. Communication between all personnel involved in measuring and analyzing data should be used to resolve any apparent anomalies before final analysis of the monitoring data can be completed. If there are any problems with the monitoring plot data (that cannot be resolved), the plot should not be used in the analysis. Errors can be reduced if the entered data are reviewed using expert judgment and, if necessary, comparison with independent data.

3.6.4. QA/QC for data archiving

Because of the relatively long-term nature of forestry activities, data archiving (maintenance and storage) will be an important component of the work. Data archiving should take several forms:.

- Original copies of the field measurement (either data sheets or electronic files) and laboratory data should be maintained in original form and placed on electronic media, and stored in a secure location, by the carbon measurement implementers.
- Copies of all data analyses, models; the final estimate of the amount of carbon sequestered; any GIS products; and a copy of the measuring and monitoring reports should all be stored in a dedicated and safe place, preferably offsite.

It is recommended that given the time frame for reporting and the pace of production of updated versions of software and new hardware for storing data, that the electronic copies of the data and report be updated periodically or converted to a format that could be accessed by any future software application.

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Chapter 1, GHG Inventories: Part I
Appendix Section 4: Calculation Methods for Estimating Carbon in Wood Products

4.1 Introduction

When wood is removed from the forest, all of the carbon does not immediately flow to the atmosphere. For example, the portion of harvested carbon stored in wood products may not be released to the atmosphere for years or even decades. If carbon remaining in wood products is not part of the accounting system, the calculation of carbon stock change for the forest area that is harvested will indicate that all of the removed carbon is immediately released to the atmosphere. Failing to account for carbon in wood products significantly overestimates emissions to the atmosphere.

Carbon pools in wood products include wood-in-use (e.g., lumber, furniture, paper) and wood products that have been discarded in landfills or recycled. In addition, the reporter may choose to account for wood burned as a fossil fuel offset. Estimation methods to account for wood burned for energy are not covered in this appendix.

This appendix describes two basic approaches to estimating carbon in wood products, and each of these approaches can be applied to two starting points for calculations, which depend on the level of products details available.

4.2 Basic Approaches

There are two basic approaches to estimate carbon in wood and paper products. <u>The first approach</u> is to track, year by year, additions to and emissions from carbon stored in wood products and landfills. For each year of harvest, the calculations must be repeated for all subsequent reporting years in order to keep track of the net amount of carbon stored in wood products. If wood products and forest carbon stocks are reported together, the stocks should be estimated for the same years.

<u>The second approach</u> is to make a single estimate of the amount of carbon that will remain stored after 100 years, for each year wood is harvested and products are produced. The calculation is done only once at the year of harvest, with the estimate added to the inventory of carbon in wood products and landfills. The underlying assumption for this approach is that after 100 years the amounts are stored permanently. This approach overestimates emissions (underestimates storage) for the first part of the product life cycle and may underestimate emissions (overestimate storage) for the last part of the product life cycle – the life beyond 100 years.

Regardless of which approach is used, accounting for carbon in wood products begins at the base period selected by the reporter. It is not necessary to estimate changes in the carbon storage in wood products that came from harvest before the base year.

4.3 Starting Points for Calculations

There are two starting points for calculating carbon in harvested wood products (Figure 1). The first is to begin the calculations with the quantity of roundwood that is harvested and removed from the forest at the time of harvest. This starting point can be used by reporters who have knowledge of timber harvested from the land but do not know the subsequent fate of the harvested wood. Regional average estimates of carbon stored in HWP each year after harvest are provided in look-up tables as described in section 4.4 below.

The second starting point is for use by a reporting entity to calculate carbon in harvested wood products based on knowledge of the unique mix of products that are produced. In this case the starting point is an inventory of the quantity of wood products, by category, produced in a year. Methods for these calculations are shown in sections 4.5 and 4.6 below.

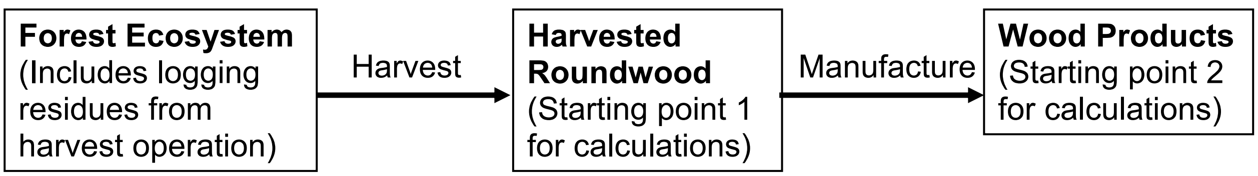

Figure 1. Flow of wood from forest to wood products showing starting points for calculations. Roundwood includes logs, bolts, and other round timber generated from harvesting trees. Logging residues include the unused portions of trees cut or killed by logging and left in the woods.

4.4 Calculations Starting with Quantity of Harvested Roundwood Using Either Approach 1 or Approach 2

The two major pools of carbon in harvested wood removed from the forest, and not emitted to the atmosphere, are in products in use and in landfills. To facilitate complete accounting of the fate of harvested carbon, two additional "pools" are defined for harvest. These are: carbon in wood products emitted to the atmosphere through combustion with concomitant energy capture; and carbon in wood products emitted to the atmosphere through combustion or decay without concomitant energy capture. The disposition of carbon in harvested wood is simulated according to methods described in Birdsey (1996) and based on Row and Phelps (1996). These calculations require additional information on harvests such as regional percentage of harvest in pulp and percentage as softwood species, for example. This was taken from the 2002 RPA forest statistics (USDA Forest Service, 2002b).

Logging residue (carbon in harvested wood left in the forest) is allocated to two of the forest ecosystem carbon pools for accounting purposes. Logging residue is assigned to either the down dead wood or the forest floor pool. A description of how to account for this material is included in other appendices to the forestry sector documentation.

A model of harvested carbon flows (HARVCARB) was used to estimate the disposition of carbon in harvested timber (Row and Phelps, 1991). HARVCARB was used to trace removals through three transformation phases. In the first phase, roundwood is processed into primary products such as lumber, plywood, paper and paperboard. In the next, primary products are transformed into end-use products such as housing, packaging, and newsprint. The first two phases generate substantial amounts of byproducts, used primarily in energy cogeneration. The third phase describes the disposal of end-use products, reflecting the length of time products remain in use, and final disposition patterns.

4.4.1 Harvest assumptions

Total harvested volume is allocated to softwood and hardwood species according to the distribution characteristic of each forest type in the 2002 RPA forest inventory dataset. Similarly, mean specific gravities of softwood and hardwood species in each forest type were determined from the FIADB (Miles and others 2001, <http://ncrs2.fs.fed.us/4801/fiadb/index.htm>) and a database of specific gravities according to species (unpublished database compiled by Linda Heath). Carbon is assumed to be 50 percent of dry weight.

We assume that wood going to mills includes a slight additional amount of wood and bark on logs. This additional mass of carbon is likely to vary according to harvest practices, species composition, and region. Lacking specific information, we assume that an additional 18 percent of biomass is included as wood and bark. This assumption is based on the relatively constant ratio of bark to wood for stems of both hardwood and softwood species described by Jenkins and others (2003). Bark specific gravity can differ from that of wood, but we do not separately estimate bark since values can be higher or lower than wood. The fate of carbon in harvest wood products is allocated according to tables of Birdsey (1996) and Row and Phelps (1996).

4.4.2 Harvest datasets and methods

The methods detailed below describe how to determine the mass of carbon going to harvested wood products and the subsequent allocation of carbon to separate pools. A specific example is provided for Upland Hardwoods in the Southeast.

Converting the harvested volume of growing stock to mass of carbon depends on assumptions about softwood versus hardwood proportions and specific gravities (Table 1), the assumed 18 percent increase for additional wood and bark, and the percent of carbon in wood. Thus, the mass (metric tons per hectare) of harvested carbon in softwood for a forest type is the product of growing stock volume, proportion of softwood, average specific gravity of softwood, multiplying by 1.18, and multiplying by 0.5, for example.

Harvested carbon in softwood and hardwood species is further allocated to pulpwood and sawtimber before it is partitioned according to the tables of Birdsey (1996) and Row and Phelps (1996). Proportion in pulpwood and sawtimber (Table 2) is determined according to region and is based on information in Table 39 of the 2002 RPA Timber Resource Tables.

4.4.3. Estimating Carbon Storage in Harvested Wood Using Approaches 1 and 2

Total harvested carbon for each pool at each year after harvest is based on the corresponding proportions in Table C and carbon mass in each of the four categories—softwood pulpwood, softwood sawtimber, hardwood pulpwood, and hardwood sawtimber. In table 3, estimates of the percentage of carbon remaining in harvested wood are shown for a 100-year period using 4 disposition categories: wood in use (durable wood products), wood products disposed in landfills, wood products and residues burned for energy, and wood products and byproducts that have decayed and returned carbon to the atmosphere. The first two categories (wood remaining in products and landfills) represent harvested carbon remaining in solid materials. Wood used for energy, although emitted to the atmosphere, may also contribute to greenhouse gas reductions by displacing carbon in fossil fuels that would have would have otherwise been used for energy and emitted.

Disposition patterns for roundwood removed from the forest in different harvest types were estimated for regions in the conterminous U.S. Harvest types reflect differences in the diameters of logs harvested and end-use patterns. Pulpwood harvests correspond to harvests of small diameter trees used to make paper. Since most paper products are short-lived, the percentage of carbon fixed in products declines sharply between the first and tenth year. Moreover, in the first year a relatively large amount is converted to emissions through burning and decomposition, reflecting lower recovery rates (quantity of product produced per unit of input) for paper compared with solid wood products. Sawtimber harvests refer to harvests of larger diameter logs used mostly for lumber and plywood. Lumber and plywood are generally long-lived and so a greater amount of harvested sawtimber remains fixed in wood products and landfills compared with harvested pulpwood. Large sawtimber harvest refers to harvest of old growth in the West. Disposition patterns for harvested old growth timber are similar to harvested sawtimber except that less carbon is intially stored in products due to greater breakage during harvest operations, and more defects in the timber.

Table 3 can be used with either approach 1 or approach 2. For approach 1, which tracks carbon in HWP over time, the proportion of carbon remaining in wood products and landfills is shown in 5-year increment beginning with the year of harvest. The original estimate of roundwood harvested is multiplied by the appropriate proportion from table 3. For approach 2, the appropriate proportion is found in the last column labeled “100 years after harvest”.

Example A: Calculation starting with quantity of harvested roundwood for upland hardwoods, Southeast.

Allocation of forest carbon at harvest is in three basic steps: determine carbon in harvested wood, allocate harvested carbon to product pools, and determine balance of carbon on-site and emitted at harvest. In this example for a 40-year old upland hardwood stand in the Southeast, 116 m^3/ha of merchantable growing stock is harvested.

The first step is to convert volume harvested (116 m^3/ha) to carbon mass in wood as metric tons per hectare (t/ha). This is then allocated to the four separate categories of harvested carbon mass needed for applying the disposition tables, these are: softwood pulpwood, softwood sawtimber, hardwood pulpwood, and hardwood sawtimber.

As described in the text, harvested carbon is the product of: volume harvested; the proportion of volume in softwood or hardwood (Table 1), average specific gravity (Table 1); an increase to account for bark, 1.18; the carbon content of wood, 0.5; and the proportion of wood allocated to pulp or sawtimber products (Table 2).

Harvested sw in pulp	$= 116\times0.065\times0.448\times1.18\times0.5\times0.399 = 0.8$ t/ha
Harvested sw in sawtimber	$= 116\times0.065\times0.448\times1.18\times0.5\times0.601 = 1.2$ t/ha
Harvested hw in pulp	$= 116\times0.935\times0.531\times1.18\times0.5\times0.523 = 17.8$ t/ha
Harvested hw in sawtimber	$= 116\times0.935\times0.531\times1.18\times0.5\times0.477 = 16.2$ t/ha
Total in harvested wood	$= 0.8+1.2+17.8+16.2 = 36.0$ t/ha

The second step is to allocate carbon to the harvested wood product pools (products in use, landfills, emitted with energy capture, emitted without energy capture) according to category of harvested carbon and the number of years since harvest.

In the same year of harvest, the estimate for carbon emitted with energy capture is based on the disposition tables (Table 3) and values calculated above:
Carbon emitted with energy capture $= 0.8\times0.436 + 1.2\times0.383 + 17.8\times0.387 + 16.2\times0.421$
$= 14.5$ t/ha

There is no carbon estimated in landfills in the harvest year. An example calculation to estimate carbon in landfills at 20 years after harvest is:
$= 0.8\times0.164 + 1.2\times0.156 + 17.8\times0.159 + 16.2\times0.133$
$= 5.3$ t/ha

The same procedure can be used to estimate the quantity of carbon in any of the carbon pools shown in table 3, for any year after harvest up to 100 years. Interpolation can be used to make estimates for specific years. This procedure works for either of the two approaches – tracking changes over time or the 100-year approach.

4.5 Calculations Starting with Quantity of Carbon in Wood Products using Approach 1 – Tracking Over Time

This section indicates how to estimate year by year additions and removals to carbon stored in HWP when the mix of products is known. The methods for each step are explained. Detailed information on the methods and data used to make estimates are shown in an annex to this appendix.

4.5.1 Step 1 – identify the base period and reporting years

Reporters must begin accounting for carbon in HWP in the first year that harvest takes place, which may be during the base or any year thereafter. Estimates of carbon in HWP must then be made for each subsequent year. It is necessary to separately track over time the carbon in HWP that came from harvest in each particular year. The amount of carbon stored in HWP that is reported for a particular year includes the amounts added in the current year plus amounts remaining in storage from harvests/products produced in prior years – back to the first year of harvest.

4.5.2 Step 2 - estimate the amount of carbon in products produced in harvest/production years

For each year of harvest/ product production year, reporters must know the kinds and amounts of products produced from the harvested wood. Factors in table 4 can be used to estimate the amount of carbon produced for each product category. This calculation is done for each year that a harvest/product production takes place.

4.5.3 Step 3 - estimate the stock of carbon in end uses and in landfills in reporting years

For each harvest/ production year an estimate must be made of carbon remaining in HWP for each reporting year. Tables 5 and 6 show the fractions of products remaining in end uses and in landfills, for 1 to 100 years after production. These fractions are applied to the amount of product carbon produced (in step 1) to estimate the amount of carbon in stored in each successive year up through the current reporting year. The calculation must be done separately for each harvest year, then added together to compute the total for the reporting year.

4.5.4 Step 4 - estimate the net change in HWP carbon stocks in the reporting year

The net change in HWP carbon stocks for a reporting year can be estimated using one of the two methods described in the General Guidelines – summing the annual changes in carbon stocks, or calculating the changes in carbon stocks from a base year. The estimates of carbon in HWP can be added to estimates for the land area of the reporting entity. Note that the estimates for HWP may be positive or negative, depending on the balance between additions to HWP from new harvesting, and losses of HWP to the atmosphere from decomposition.

Example B. Tracking carbon in harvested wood products each year over time.

In order to calculate the amount of carbon in HWP in use and in landfills in for the years 2000-2003, the company produced Tables A and B. Table A shows total lumber and plywood production since 2000 in columns 1 and 2. The volumes are converted to tons of carbon in columns 3 and 4 using factors from Table 4 in the text. Table B shows the amount of products left in end uses and in landfills in 2000, 2001, 2002 and 2003. The fraction of each product left in end uses after a given number of years is derived from Table 5 in the text, and the fraction left in landfills is derived from Table 6 in the text.

Table A. Production of harvested wood products and conversion to carbon.

Year	softwood lumber	softwood plywood	softwood lumber	softwood plywood
	1000 board feet	1000 square feet 3/8 inch	tons carbon	tons carbon
2000	93000	183000	45384	49959
2001	85000	175000	41480	47775
2002	95000	170000	46360	46410
2003	100000	173000	48800	47229

Table B. Carbon in end uses and landfills for each year after harvest

Year of harvest	Carbon in end uses				Carbon in landfills			
	In 2000	In 2001	In 2002	In 2003	In 2000	In 2001	In 2002	In 2003
	tons carbon	tons carbon	tons carbon	tons carbon	tons carbon	tons carbon	tons carbon	tons carbon
2000	91015	87020	83323	79897	2869	5487	7880	10070
2001		85167	81398	77911		2710	5179	7437
2002			88636	84814			2740	5244
2003				91779				2817
Total carbon	91015	172187	253357	334401	2869	8197	15799	25568

From table B, the inventory of HWP carbon for each year can be calculated as the sum of carbon in end uses and carbon in landfills:

Year	2000	2001	2002	2003
Total carbon (MtC)	93,884	180,384	269,156	359,969

These estimates can be used with one of the reporting methods for carbon stocks described in the general guidelines.

4.6 Calculations Starting with Quantity of Carbon in Wood Products using Approach 2 – Storage 100 years after harvest/ product production

This section indicates how to estimate carbon stored in HWP 100 years after harvest/ product production. The methods for each step are explained.

4.6.1 Step 1 – identify the base year and reporting years

Reporters must begin accounting for carbon in HWP in the first year that harvest takes place, which may be during the base or any year thereafter. Estimation of carbon stored in HWP from a given year's harvest/production is done only one time – an estimate of the amount stored after 100 years. The amount of carbon stored in HWP that is reported for a particular year includes the amounts added in the current year plus amounts estimated in storage from harvests/products produced in prior years – back to the first year of harvest.

4.6.2. Step 2 - estimate the amount of carbon in products produced in harvest/ production years

For each year of harvest/ product production year, reporters must know the kinds and amounts of products produced from the harvested wood. Factors in table 4 can be used to estimate the amount of HWP carbon produced for each product category. This calculation is done for each year that a harvest/product production takes place.

4.6.3 Step 3 - estimate the stock of carbon in end uses and in landfills in reporting years

For each harvest/ production year estimate the amount of HWP carbon remaining after 100 years 1) in products in use and 2) in landfills using fractions in tables 5 and 6. The calculation must be done separately for each harvest/ production production year, then added together to get the total for the reporting year.

4.6.4 Step 4 - estimate the net change in HWP carbon stocks in the reporting year

The net change in HWP carbon stocks for a reporting year can be estimated using one of the two methods described in the General Guidelines – summing the annual changes in carbon stocks, or calculating the changes in carbon stocks from a base year. The estimates of carbon in HWP can be added to estimates for the land area of the reporting entity.

Example C. Estimated carbon stored 100 years after harvest.

This Example uses the same company data as for Example A to estimate amounts reported for 2000-2003 using estimates of amounts stored after 100 years. As for Example A Table A shows total lumber and plywood production since 2000 for lumber and plywood columns 1 and 2. The volumes are converted to tons of carbon in columns 3 and 4 using factors from Table 4 in the text. Table C shows the amount of carbon in products produced in each year of harvest (from Table A) and the amount of carbon remaining in use and in landfills after 100 years using factors from Tables 5 and 6.

Table A. Production of harvested wood products and conversion to carbon.

Year	softwood lumber	softwood plywood	softwood lumber	softwood plywood
	1000 board feet	1000 square feet 3/8 inch	tons carbon	tons carbon
2000	93000	183000	45384	49959
2001	85000	175000	41480	47775
2002	95000	170000	46360	46410
2003	100000	173000	48800	47229

Table B. Carbon in end uses and landfills 100 years after harvest

Year of harvest	Carbon in end uses 100 years after harvest				Carbon in landfills 100 years after harvest			
	In 2000 tons carbon	In 2001 tons carbon	In 2002 tons carbon	In 2003 tons carbon	In 2000 tons carbon	In 2001 tons carbon	In 2002 tons carbon	In 2003 tons carbon
2000	22860	22860	22860	22860	38364	38364	38364	38364
2001		21411	21411	21411		35909	35909	35909
2002			22219	22219			37340	37340
2003				22990				38656
Total carbon	22860	44271	66490	89480	38364	74273	111613	150269
Example calculation for 2000: 22860 = 45384*0.234 + 49959*0.245								

From table B, the inventory of HWP carbon for each year can be calculated as the cumulative sum of carbon in end uses and carbon in landfills 100 years after harvest:

Year	2000	2001	2002	2003
Total carbon (MtC)	61,224	118,545	178,103	239,749

These estimates can be used with one of the reporting methods for carbon stocks described in the general guidelines.

4.7 Rating Estimates for Wood Products

The rating for estimates of carbon in wood products depends on how well the estimates represent the specific products produced by the reporting entity. If the selected estimation approach is a good fit, it should result in a "B" rating. The methods presented in this appendix, which are applied to the specific mix of products produced by an entity, should result in a "B" rating. Use of the wood product estimates included with the regional look-up tables (separate appendix) will receive a "C" rating because the estimates are based on regional statistics of roundwood harvest with little consideration of the specific product mix produced by an entity. A model developed for a specific entity may achieve a higher rating, especially if the model is validated as described in the modeling appendix (separate from this document).

Rating	*Points*	*Characterization*	*Typical Description for Forestry*
A	4	Most accurate method (within 10 % of true value)	Model is validated with data specific to the product mix of the entity.
B	3	Adequate accuracy (within 20 % of true value)	Use of the product-specific methods presented in this appendix.
C	2	Marginal accuracy (within 30 % of true value)	Use of the harvested wood estimates presented in the look-up tables (separate appendix).
D	1	Inadequate accuracy	Use of global estimates.

Table 1. Average proportion of growing stock volume and average specific gravity of wood in softwood (sw) and hardwood (hw) species according to region and forest type. Proportion of volume is based on 2002 RPA data and specific gravity is from an unpublished database and the FIADB; see appropriate citations in text. High and medium productivity levels are defined with the corresponding default tables.

Region	Forest Type	Proportion		Average specific gravity	
		sw	hw	sw	hw
Northeast					
	Aspen & Birch	0.233	0.767	0.357	0.430
	Elm, Ash, Red Maple	0.146	0.854	0.367	0.511
	Maple, Beech, Birch	0.134	0.866	0.369	0.520
	Oak & Hickory	0.043	0.957	0.391	0.533
	Oak & Pine	0.487	0.513	0.388	0.526
	Spruce & Balsam Fir	0.847	0.153	0.350	0.483
	White, Red & Jack Pine	0.737	0.263	0.363	0.509
Northern Lake States					
	Aspen & Birch	0.157	0.843	0.355	0.397
	Jack Pine	0.878	0.122	0.392	0.453
	Lowland Hardwood	0.138	0.862	0.339	0.454
	Maple & Beech	0.119	0.881	0.356	0.495
	Oak & Hickory	0.053	0.947	0.380	0.533
	Red Pine	0.906	0.094	0.392	0.453
	Spruce & Balsam Fir	0.703	0.297	0.347	0.435
	Swamp Conifer	0.873	0.127	0.347	0.435
	White Pine	0.827	0.173	0.392	0.453
Northern Prairie States					
	Lowland Hardwood	0.008	0.992	0.433	0.464
	Maple & Beech	0.012	0.988	0.429	0.512
	Oak & Hickory	0.019	0.981	0.436	0.557
	Oak-Pine	0.461	0.539	0.429	0.519
	Pines	0.828	0.172	0.432	0.508
Pacific Southwest					
	Douglas-fir	0.859	0.141	0.427	0.546
	True Fir	0.999	0.001	0.371	0.555
	Hardwood	0.409	0.591	0.417	0.571
	Mixed Conifer	0.914	0.086	0.387	0.514
	Ponderosa Pine	0.937	0.063	0.384	0.567
	Redwood	0.924	0.076	0.358	0.563
Pacific Northwest, Eastside					
	Douglas-fir & Larch	0.993	0.007	0.433	0.435
	True Fir	0.993	0.007	0.373	0.387
	Hardwood	0.438	0.562	0.420	0.411
	Lodgepole Pine	0.996	0.004	0.390	0.391
	Ponderosa Pine	0.998	0.002	0.388	0.550
Pacific Northwest, Westside					
	Douglas-fir, high productivity	0.955	0.045	0.440	0.418
	Douglas-fir, medium productivity	0.936	0.064	0.440	0.418

Fir & Spruce, high productivity	0.990	0.010	0.394	0.432
Fir & Spruce, medium productivity	0.983	0.017	0.393	0.436
Hardwood Mix	0.519	0.481	0.401	0.453
Red Alder, high productivity	0.406	0.594	0.408	0.381
Red Alder, medium productivity	0.379	0.621	0.408	0.381
Western Hemlock, high productivity	0.971	0.029	0.407	0.377
Western Hemlock, medium productivity	0.957	0.043	0.407	0.377
Rocky Mountain, North				
Douglas-fir	0.991	0.009	0.424	0.415
Fir & Spruce	0.996	0.004	0.354	0.397
Lodgepole Pine	0.997	0.003	0.379	0.425
Ponderosa Pine	0.998	0.002	0.390	0.336
Rocky Mountain, South				
Douglas-fir	0.960	0.040	0.430	0.444
Fir & Spruce	0.953	0.047	0.342	0.377
High Elevation	0.988	0.012	0.368	0.505
Lodgepole Pine	0.985	0.015	0.376	0.353
Ponderosa Pine	0.991	0.009	0.385	0.591
South Central				
Lowland Hardwood	0.121	0.879	0.440	0.511
Natural Pine, high productivity	0.868	0.132	0.470	0.523
Natural Pine, medium productivity	0.869	0.131	0.477	0.522
Oak-Pine, high productivity	0.590	0.410	0.467	0.536
Oak-Pine, medium productivity	0.569	0.431	0.467	0.536
Planted Pine, high productivity	0.938	0.062	0.476	0.522
Planted Pine, medium productivity	0.948	0.052	0.476	0.522
Upland Hardwoods	0.075	0.925	0.452	0.543
Southeast				
Lowland Hardwood	0.212	0.788	0.439	0.487
Natural Pine, high productivity	0.840	0.160	0.474	0.505
Natural Pine, medium productivity	0.865	0.135	0.486	0.507
Oak-Pine, high productivity	0.481	0.519	0.467	0.521
Oak-Pine, medium productivity	0.498	0.502	0.467	0.521
Planted Pine, high productivity	0.952	0.048	0.487	0.507
Planted Pine, medium productivity	0.956	0.044	0.495	0.509
Upland Hardwoods	0.065	0.935	0.448	0.531

Table 2. Estimated proportion of softwood (sw) and hardwood (hw) species allocated to pulpwood or sawtimber products according to region. These values were used to develop estimates of carbon in harvested wood products for the harvest scenario default tables and are based on Table 39 of the 2002 RPA Timber Resource Tables.

Region	Pulpwood		Sawtimber	
	sw	hw	sw	hw
Northeast	0.444	0.370	0.556	0.630
North Central	0.597	0.337	0.403	0.663
South Central	0.357	0.526	0.643	0.474
Southeast	0.399	0.523	0.601	0.477
Rocky Mountains	0.043	0.000	0.957	1.000
Pacific Northwest	0.022	0.044	0.978	0.956
Pacific Southwest	0.000	0.000	1.000	1.000

Table 3. Disposition patterns of harvested wood by region and harvest type, 100-year period.

Region - harvest type[1] / Disposition[2]	Years After Harvest										
	0	10	20	30	40	50	60	70	80	90	100
	(Proportion of Initial Carbon Harvested)										
Southeast - Softwood Pulpwood											
Products	0.301	0.067	0.047	0.039	0.034	0.031	0.029	0.028	0.026	0.025	0.024
Landfills	0.000	0.161	0.164	0.157	0.150	0.143	0.135	0.127	0.121	0.114	0.109
Energy	0.436	0.453	0.454	0.455	0.455	0.455	0.455	0.455	0.456	0.456	0.456
Emissions	0.263	0.319	0.335	0.349	0.360	0.371	0.381	0.390	0.398	0.405	0.411
Southeast - Softwood Sawtimber											
Products	0.472	0.281	0.241	0.213	0.181	0.165	0.153	0.142	0.133	0.126	0.121
Landfills	0.000	0.134	0.156	0.167	0.182	0.185	0.185	0.185	0.183	0.180	0.176
Energy	0.383	0.396	0.399	0.401	0.403	0.404	0.405	0.406	0.407	0.407	0.408
Emissions	0.146	0.188	0.205	0.219	0.233	0.245	0.257	0.267	0.278	0.287	0.295
Southeast - Hardwood Pulpwood											
Products	0.302	0.066	0.049	0.042	0.036	0.033	0.031	0.029	0.027	0.026	0.026
Landfills	0.000	0.159	0.159	0.152	0.146	0.137	0.130	0.123	0.116	0.109	0.104
Energy	0.387	0.404	0.405	0.405	0.406	0.406	0.406	0.406	0.406	0.407	0.407
Emissions	0.312	0.371	0.387	0.401	0.413	0.423	0.433	0.442	0.450	0.457	0.464
Southeast - Hardwood Sawtimber											
Products	0.271	0.117	0.081	0.067	0.057	0.051	0.047	0.042	0.039	0.037	0.035
Landfills	0.000	0.111	0.133	0.137	0.138	0.136	0.134	0.131	0.128	0.125	0.121
Energy	0.421	0.432	0.434	0.435	0.436	0.437	0.437	0.437	0.437	0.438	0.438
Emissions	0.308	0.339	0.352	0.360	0.369	0.376	0.383	0.389	0.395	0.401	0.406
South Central - Softwood Pulpwood											
Products	0.302	0.067	0.047	0.039	0.034	0.031	0.029	0.028	0.026	0.025	0.024
Landfills	0.000	0.162	0.165	0.158	0.151	0.143	0.135	0.128	0.121	0.115	0.109
Energy	0.437	0.454	0.455	0.456	0.456	0.456	0.457	0.457	0.457	0.457	0.457
Emissions	0.261	0.317	0.333	0.347	0.359	0.369	0.379	0.388	0.396	0.403	0.410
South Central - Softwood Sawtimber											
Products	0.465	0.294	0.254	0.225	0.192	0.174	0.162	0.150	0.140	0.133	0.127
Landfills	0.000	0.121	0.143	0.157	0.174	0.178	0.180	0.180	0.179	0.176	0.174
Energy	0.333	0.345	0.347	0.349	0.352	0.353	0.354	0.355	0.356	0.356	0.357
Emissions	0.202	0.241	0.255	0.269	0.283	0.294	0.305	0.316	0.325	0.334	0.343

Table 3. Disposition patterns of harvested wood by region and harvest type, 100-year period (cont).

Region - harvest type[1] / Disposition[2]	Years After Harvest: 0	10	20	30	40	50	60	70	80	90	100
	(Proportion of Initial Carbon Harvested)										
South Central - Hardwood Pulpwood											
Products	0.301	0.066	0.049	0.042	0.036	0.033	0.031	0.029	0.027	0.026	0.025
Landfills	0.000	0.158	0.159	0.152	0.145	0.137	0.130	0.122	0.116	0.109	0.104
Energy	0.386	0.403	0.404	0.405	0.405	0.405	0.406	0.406	0.406	0.406	0.406
Emissions	0.313	0.372	0.388	0.401	0.414	0.424	0.434	0.443	0.451	0.458	0.465
South Central - Hardwood Sawtimber											
Products	0.263	0.113	0.078	0.065	0.055	0.050	0.045	0.041	0.038	0.035	0.034
Landfills	0.000	0.108	0.129	0.132	0.134	0.132	0.129	0.127	0.124	0.120	0.118
Energy	0.426	0.436	0.439	0.440	0.440	0.441	0.441	0.441	0.442	0.442	0.442
Emissions	0.312	0.342	0.354	0.363	0.371	0.378	0.384	0.391	0.397	0.402	0.407
Northeast - Softwood Pulpwood											
Products	0.300	0.067	0.046	0.039	0.034	0.031	0.029	0.028	0.026	0.025	0.024
Landfills	0.000	0.161	0.164	0.157	0.150	0.143	0.135	0.127	0.121	0.114	0.109
Energy	0.448	0.464	0.466	0.466	0.467	0.467	0.467	0.467	0.467	0.467	0.467
Emissions	0.252	0.308	0.324	0.337	0.349	0.360	0.369	0.378	0.386	0.393	0.400
Northeast - Softwood Sawtimber											
Products	0.330	0.193	0.166	0.147	0.125	0.114	0.105	0.097	0.091	0.086	0.083
Landfills	0.000	0.096	0.111	0.119	0.129	0.130	0.130	0.129	0.128	0.126	0.124
Energy	0.376	0.386	0.388	0.389	0.391	0.391	0.392	0.393	0.393	0.394	0.394
Emissions	0.293	0.324	0.336	0.346	0.356	0.364	0.373	0.380	0.387	0.394	0.400
Northeast - Hardwood Pulpwood											
Products	0.291	0.064	0.047	0.040	0.035	0.032	0.030	0.028	0.027	0.025	0.025
Landfills	0.000	0.153	0.154	0.147	0.141	0.133	0.125	0.119	0.112	0.106	0.100
Energy	0.379	0.395	0.396	0.397	0.397	0.397	0.398	0.398	0.398	0.398	0.398
Emissions	0.330	0.388	0.403	0.416	0.428	0.438	0.448	0.456	0.464	0.471	0.477
Northeast - Hardwood Sawtimber											
Products	0.218	0.092	0.064	0.054	0.046	0.041	0.037	0.034	0.031	0.029	0.028
Landfills	0.000	0.091	0.107	0.110	0.111	0.109	0.107	0.105	0.103	0.100	0.097
Energy	0.483	0.491	0.493	0.494	0.495	0.495	0.495	0.495	0.496	0.496	0.496
Emissions	0.299	0.325	0.335	0.342	0.349	0.355	0.361	0.366	0.371	0.375	0.379

Table 3. Disposition patterns of harvested wood by region and harvest type, 100-year period (cont).

Region - harvest type[1] Disposition[2]	Years After Harvest 0	10	20	30	40	50	60	70	80	90	100
	(Proportion of Initial Carbon Harvested)										
North Central - Softwood Pulpwood											
Products	0.303	0.067	0.047	0.040	0.034	0.031	0.029	0.028	0.026	0.025	0.025
Landfills	0.000	0.163	0.165	0.159	0.151	0.144	0.136	0.128	0.121	0.115	0.109
Energy	0.443	0.460	0.461	0.462	0.462	0.463	0.463	0.463	0.463	0.463	0.463
Emissions	0.254	0.310	0.326	0.340	0.352	0.363	0.372	0.381	0.389	0.396	0.403
North Central - Softwood Sawtimber											
Products	0.330	0.168	0.143	0.127	0.111	0.101	0.093	0.085	0.078	0.073	0.069
Landfills	0.000	0.113	0.123	0.127	0.132	0.131	0.129	0.129	0.127	0.125	0.122
Energy	0.458	0.470	0.471	0.473	0.474	0.474	0.475	0.476	0.476	0.477	0.477
Emissions	0.212	0.250	0.262	0.273	0.284	0.293	0.302	0.311	0.319	0.326	0.332
North Central - Hardwood Pulpwood											
Products	0.284	0.063	0.046	0.039	0.034	0.031	0.029	0.027	0.026	0.025	0.024
Landfills	0.000	0.150	0.150	0.143	0.137	0.130	0.122	0.116	0.110	0.104	0.098
Energy	0.380	0.396	0.397	0.397	0.398	0.398	0.398	0.398	0.398	0.398	0.398
Emissions	0.336	0.392	0.407	0.420	0.431	0.441	0.451	0.459	0.467	0.473	0.480
North Central - Hardwood Sawtimber											
Products	0.235	0.101	0.070	0.058	0.049	0.044	0.041	0.037	0.034	0.032	0.030
Landfills	0.000	0.098	0.116	0.118	0.119	0.118	0.116	0.113	0.111	0.108	0.105
Energy	0.470	0.479	0.481	0.482	0.483	0.483	0.483	0.484	0.484	0.484	0.484
Emissions	0.295	0.323	0.333	0.341	0.348	0.355	0.361	0.366	0.371	0.376	0.381
Rocky Mountains - All Softwoods											
Pproducts	0.507	0.374	0.330	0.294	0.251	0.228	0.211	0.195	0.181	0.171	0.163
Landfills	0.000	0.089	0.118	0.140	0.166	0.176	0.181	0.186	0.189	0.189	0.188
Energy	0.348	0.366	0.370	0.372	0.375	0.377	0.378	0.380	0.381	0.382	0.382
Emissions	0.144	0.170	0.183	0.195	0.208	0.219	0.229	0.240	0.250	0.259	0.267
Pacific Northwest (West Side) - Softwood Pulpwood											
Products	0.346	0.077	0.054	0.045	0.039	0.036	0.034	0.032	0.030	0.029	0.028
Landfills	0.000	0.186	0.189	0.181	0.173	0.164	0.155	0.146	0.139	0.131	0.125
Energy	0.470	0.489	0.491	0.491	0.492	0.492	0.492	0.492	0.492	0.492	0.492
Emissions	0.184	0.248	0.267	0.282	0.296	0.308	0.319	0.330	0.339	0.347	0.355

Table 3. Disposition patterns of harvested wood by region and harvest type, 100-year period (cont).

Region - harvest type[1] / Disposition[2]	Years After Harvest										
	0	10	20	30	40	50	60	70	80	90	100
	(Proportion of Initial Carbon Harvested)										
Pacific Northwest (West Side) - Softwood Sawtimber											
Products	0.501	0.371	0.331	0.299	0.264	0.241	0.221	0.197	0.178	0.165	0.156
Landfills	0.000	0.092	0.116	0.133	0.153	0.163	0.170	0.180	0.186	0.187	0.187
Energy	0.244	0.253	0.256	0.258	0.261	0.262	0.264	0.266	0.268	0.269	0.269
Emissions	0.255	0.284	0.297	0.309	0.322	0.333	0.345	0.357	0.369	0.379	0.388
Pacific Northwest (West Side) - Old-growth Softwoods											
Products	0.511	0.387	0.346	0.313	0.276	0.252	0.231	0.206	0.186	0.173	0.162
Landfills	0.000	0.088	0.113	0.132	0.153	0.163	0.172	0.182	0.188	0.191	0.191
Energy	0.225	0.234	0.237	0.239	0.242	0.244	0.245	0.247	0.249	0.250	0.251
Emissions	0.264	0.291	0.304	0.316	0.329	0.340	0.352	0.364	0.376	0.386	0.396
Pacific Northwest (East Side) - All Softwoods											
Products	0.471	0.348	0.305	0.270	0.227	0.206	0.192	0.179	0.169	0.162	0.155
Landfills	0.000	0.083	0.112	0.133	0.160	0.170	0.173	0.176	0.176	0.176	0.175
Energy	0.285	0.301	0.304	0.307	0.310	0.311	0.312	0.313	0.314	0.315	0.315
Emissions	0.244	0.268	0.279	0.290	0.303	0.313	0.322	0.331	0.340	0.348	0.355
Pacific Southwest - All Softwoods											
Products	0.437	0.314	0.276	0.244	0.207	0.188	0.174	0.162	0.152	0.144	0.138
Landfills	0.000	0.082	0.106	0.125	0.148	0.156	0.159	0.162	0.164	0.163	0.162
Energy	0.292	0.308	0.311	0.314	0.316	0.318	0.319	0.320	0.321	0.321	0.322
Emissions	0.271	0.295	0.306	0.317	0.329	0.338	0.347	0.356	0.364	0.372	0.379
Pacific Northwest (West Side) - All Hardwoods											
Products	0.232	0.088	0.061	0.052	0.045	0.041	0.038	0.034	0.032	0.030	0.028
Landfills	0.000	0.103	0.117	0.118	0.116	0.114	0.111	0.108	0.105	0.103	0.099
Energy	0.477	0.487	0.489	0.490	0.490	0.491	0.491	0.491	0.491	0.492	0.492
Emissions	0.291	0.322	0.332	0.340	0.348	0.354	0.360	0.366	0.372	0.377	0.381
Other West - All Hardwoods											
Products	0.227	0.087	0.061	0.052	0.045	0.041	0.037	0.034	0.031	0.029	0.028
Landfills	0.000	0.094	0.109	0.110	0.109	0.107	0.104	0.103	0.100	0.097	0.094
Energy	0.457	0.475	0.477	0.477	0.478	0.478	0.479	0.479	0.479	0.479	0.479
Emissions	0.317	0.344	0.354	0.361	0.368	0.374	0.379	0.385	0.390	0.394	0.398

[1]Average size and use category, and species group, of harvested timber.
[2]Category in which the harvested carbon resides at the specified year.

Table 4 - Factors to Convert wood and paper products in customary units to tons carbon

Solidwood product	Units	Factor to convert Units to tons carbon
1. Softwood lumber / laminated veneer lumber/ glulam lumber/ I-joists	Thousand Board Feet	0.488
2. Hardwood lumber	Thousand Board Feet	0.844
3. Softwood plywood	Thousand Square feet 3/8 inch	0.273
4. Oriented strandboard	Thousand Square feet 3/8 inch	0.313
5. Non structural panels (average)	Thousand Square feet 3/8 inch	0.340
Hardwood veneer/ plywood	Thousand Square feet 3/8 inch	0.328
Particleboard / Medium density fiberboard	Thousand Square feet 3/4 inch	0.703
Hardboard	Thousand Square feet 1/8 inch	0.156
Insulation board	Thousand Square feet 1/2 inch	0.184
6. Other industrial products	Thousand cubic feet	8.250
7. Paper	Tons, air dry	0.45

Table 5 - Fraction of products remaining in end uses 1 to 100 years after production

	Softwood lumber	Hardwood lumber	Softwood plywood	OSB	Non structural panels	Paper
	1.00	1.00	1.00	1.00	1.00	1.00
1	0.973	0.938	0.976	0.983	0.969	0.707
2	0.947	0.882	0.952	0.967	0.939	0.500
3	0.922	0.831	0.930	0.952	0.911	0.354
4	0.898	0.784	0.909	0.937	0.883	0.250
5	0.875	0.741	0.888	0.922	0.857	0.177
6	0.854	0.701	0.869	0.908	0.832	0.125
7	0.833	0.665	0.850	0.895	0.808	0.088
8	0.813	0.631	0.832	0.881	0.785	0.063
9	0.795	0.600	0.815	0.869	0.763	0.044
10	0.777	0.571	0.798	0.856	0.741	0.031
11	0.760	0.545	0.782	0.844	0.721	0.022
12	0.743	0.520	0.767	0.832	0.701	0.016
13	0.728	0.497	0.752	0.821	0.683	0.011
14	0.712	0.476	0.738	0.810	0.665	0.008
15	0.698	0.456	0.724	0.799	0.647	0.006
16	0.684	0.438	0.711	0.789	0.630	0.004
17	0.671	0.421	0.698	0.778	0.614	0.003
18	0.658	0.405	0.685	0.768	0.599	0.002
19	0.645	0.389	0.673	0.759	0.584	0.001
20	0.633	0.375	0.662	0.749	0.569	0.001
21	0.622	0.362	0.650	0.740	0.555	0.001
22	0.611	0.349	0.639	0.731	0.542	0.000
23	0.600	0.337	0.629	0.722	0.529	0.000
24	0.589	0.326	0.619	0.713	0.517	0.000
25	0.579	0.316	0.609	0.705	0.505	0.000
26	0.569	0.306	0.599	0.697	0.493	0.000
27	0.560	0.296	0.589	0.689	0.482	0.000
28	0.551	0.287	0.580	0.681	0.471	0.000
29	0.542	0.278	0.571	0.673	0.460	0.000
30	0.533	0.270	0.563	0.666	0.450	0.000
31	0.525	0.263	0.554	0.658	0.440	0.000
32	0.517	0.255	0.546	0.651	0.431	0.000
33	0.509	0.248	0.538	0.644	0.421	0.000
34	0.501	0.241	0.530	0.637	0.412	0.000
35	0.494	0.235	0.522	0.630	0.404	0.000
36	0.487	0.229	0.515	0.623	0.395	0.000
37	0.480	0.223	0.508	0.617	0.387	0.000
38	0.473	0.217	0.500	0.610	0.379	0.000
39	0.466	0.211	0.493	0.604	0.372	0.000
40	0.459	0.206	0.487	0.598	0.364	0.000
41	0.453	0.201	0.480	0.592	0.357	0.000
42	0.447	0.196	0.474	0.586	0.350	0.000
43	0.441	0.191	0.467	0.580	0.343	0.000
44	0.435	0.187	0.461	0.574	0.337	0.000
45	0.429	0.183	0.455	0.568	0.330	0.000
46	0.423	0.178	0.449	0.563	0.324	0.000
47	0.418	0.174	0.443	0.557	0.318	0.000

48	0.413	0.170	0.437	0.552	0.312	0.000
49	0.407	0.166	0.432	0.546	0.306	0.000
50	0.402	0.163	0.426	0.541	0.301	0.000
55	0.378	0.146	0.401	0.516	0.275	0.000
60	0.356	0.131	0.377	0.493	0.252	0.000
65	0.336	0.119	0.356	0.471	0.232	0.000
70	0.318	0.108	0.336	0.450	0.214	0.000
75	0.301	0.098	0.318	0.431	0.198	0.000
80	0.286	0.090	0.301	0.413	0.183	0.000
85	0.271	0.082	0.286	0.395	0.170	0.000
90	0.258	0.075	0.271	0.379	0.159	0.000
95	0.246	0.069	0.258	0.364	0.148	0.000
100	0.234	0.064	0.245	0.349	0.138	0.000

Table 6 - Fraction of products remaining in landfills 1 to 100 years after production

	Softwood lumber	Hardwood lumber	Softwood plywood	OSB	Non structural panels	Paper
1	0.018	0.041	0.016	0.011	0.021	0.097
2	0.035	0.078	0.032	0.021	0.040	0.162
3	0.051	0.111	0.046	0.032	0.059	0.207
4	0.067	0.141	0.060	0.041	0.076	0.235
5	0.081	0.168	0.073	0.050	0.093	0.254
6	0.094	0.193	0.085	0.059	0.108	0.264
7	0.107	0.215	0.096	0.068	0.123	0.270
8	0.119	0.235	0.107	0.076	0.137	0.272
9	0.130	0.254	0.118	0.084	0.151	0.272
10	0.141	0.270	0.128	0.091	0.164	0.270
11	0.151	0.286	0.137	0.098	0.176	0.267
12	0.161	0.299	0.146	0.105	0.187	0.263
13	0.170	0.312	0.155	0.112	0.198	0.259
14	0.179	0.324	0.163	0.118	0.208	0.255
15	0.187	0.334	0.171	0.124	0.218	0.250
16	0.194	0.344	0.178	0.130	0.228	0.246
17	0.202	0.353	0.185	0.136	0.236	0.242
18	0.209	0.361	0.192	0.142	0.245	0.237
19	0.216	0.368	0.199	0.147	0.253	0.233
20	0.222	0.375	0.205	0.152	0.261	0.229
21	0.228	0.381	0.211	0.157	0.268	0.226
22	0.234	0.387	0.217	0.162	0.275	0.222
23	0.239	0.393	0.222	0.167	0.282	0.218
24	0.245	0.398	0.228	0.171	0.288	0.215
25	0.250	0.402	0.233	0.176	0.294	0.212
26	0.255	0.406	0.238	0.180	0.300	0.209
27	0.259	0.410	0.242	0.184	0.306	0.206
28	0.264	0.414	0.247	0.188	0.311	0.203
29	0.268	0.418	0.252	0.192	0.316	0.201
30	0.272	0.421	0.256	0.196	0.321	0.198
31	0.276	0.424	0.260	0.200	0.326	0.196
32	0.280	0.427	0.264	0.204	0.331	0.194
33	0.284	0.429	0.268	0.207	0.335	0.191
34	0.288	0.432	0.272	0.211	0.339	0.189
35	0.291	0.434	0.275	0.214	0.343	0.187
36	0.294	0.436	0.279	0.217	0.347	0.186
37	0.298	0.438	0.282	0.221	0.351	0.184
38	0.301	0.440	0.286	0.224	0.354	0.182
39	0.304	0.442	0.289	0.227	0.358	0.181
40	0.307	0.444	0.292	0.230	0.361	0.179
41	0.310	0.446	0.295	0.233	0.364	0.178
42	0.313	0.447	0.298	0.236	0.367	0.176
43	0.315	0.449	0.301	0.239	0.370	0.175

44	0.318	0.451	0.304	0.242	0.373	0.174
45	0.320	0.452	0.307	0.244	0.376	0.173
46	0.323	0.453	0.310	0.247	0.379	0.171
47	0.325	0.455	0.312	0.250	0.381	0.170
48	0.328	0.456	0.315	0.252	0.384	0.169
49	0.330	0.457	0.317	0.255	0.386	0.168
50	0.332	0.458	0.320	0.257	0.388	0.167
55	0.343	0.463	0.331	0.269	0.399	0.163
60	0.352	0.468	0.342	0.280	0.409	0.160
65	0.361	0.472	0.351	0.290	0.417	0.158
70	0.369	0.475	0.360	0.300	0.424	0.156
75	0.376	0.478	0.368	0.309	0.430	0.155
80	0.383	0.481	0.375	0.317	0.436	0.153
85	0.389	0.484	0.382	0.325	0.441	0.152
90	0.395	0.486	0.389	0.333	0.446	0.152
95	0.400	0.488	0.394	0.340	0.450	0.151
100	0.405	0.490	0.400	0.347	0.454	0.151

Annex – Detailed data used to calculated harvested wood products year by year decay

Conversion factors in Table 4 were computed using data in Table A1 below

The fraction of a product remaining in use n years after production (shown in Table 5) was developed by determining the fraction allocated to each of several uses and the fraction left in each use after n years. The fraction left in a particular end use after n years is determined using a first order decay function that has a given half life. The first order decay function removes a fixed fraction of material from the amount remaining each year. The allocation of different products to end uses is shown in Table A2 and the half life for products in those end uses are shown in Table A3.

Using these allocation factors and half life estimates the fraction of products left in end uses after n years as shown in Table 2 were developed using the following equation

Fraction remaining in year n
= (fraction used in single family houses) x $e^{-(-n*\ln(2)/\text{ half life for sf houses})}$
+ (fraction used in multi family houses) x $e^{(-n*\ln(2)/\text{ half life for mf houses})}$
+ (fraction used in Mobile homes) x $e^{(-n*\ln(2)/\text{ half life mobil homes})}$
+ (fraction used in repair & alteration) x $e^{(-n*\ln(2)/\text{ half life repair})}$
+ (fraction used in non residential except railroads) x $e^{(-n*\ln(2)/\text{ half life non res ex rr})}$
+ (fraction used in railroad ties) x $e^{(-n*\ln(2)/\text{ half life rr ties})}$
+ (fraction used in railroad cars) x $e^{(-n*\ln(2)/\text{ half life rr cars})}$
+ (fraction used in household furniture) x $e^{(-n*\ln(2)/\text{ half life hh frun})}$
+ (fraction used in commercial furniture) x $e^{(-n*\ln(2)/\text{ half life com furn})}$
+ (fraction used in other manufacturing) x $e^{(-n*\ln(2)/\text{ half life oth manf})}$
+ (fraction used in wood containers) x $e^{(-n*\ln(2)/\text{ half life wood cont})}$
+ (fraction used in pallets) x $e^{(-n*\ln(2)/\text{ half life pallets})}$
+ (fraction used in dunnage) x $e^{(-n*\ln(2)/\text{ half life dunnage})}$
+ (fraction used in other uses) x $e^{(-n*\ln(2)/\text{ half life other uses})}$
+ (fraction used in exports) x $e^{(-n*\ln(2)/\text{ half life exports})}$

The fraction of a product remaining in landfills n years after production (shown in Table 5) was determined by taking the amount of product discarded from one year to the next as determined by table 7, then taking the fraction which is sent to landfills and placing it in two pools (table A4). One pool provides permanent sequestration and the second pool decays using a first order decay function. See Table A5 for the fractions of wood and paper that are permanently sequestered and the half life for the pool that decays.

Table A1 - Factors to Convert wood and paper products in customary units to tons carbon - (Parameter CF)

Solidwood product	Units	Cubic feet per Unit (1)	Lbs per cubic foot (2)	Fraction of Product which is Wood fiber (3)	Factor to convert Units to tons carbon (4)
1. Softwood lumber / laminated veneer lumber/ glulam lumber/ I-joists	Thousand Board Feet	59.17	33.0	1.00	0.488
2. Hardwood lumber	Thousand Board Feet	83.33	40.5	1.00	0.844
3. Softwood plywood	Thousand Square feet 3/8 inch	31.25	35.0	0.95	0.260
4. Oriented strandboard	Thousand Square feet 3/8 inch	31.25	40.0	0.97	0.303
5. Non structural panels (average)	Thousand Square feet 3/8 inch	31.25			0.319
Hardwood veneer/ plywood	Thousand Square feet 3/8 inch	31.25	42.0	0.96	0.312
Particleboard / Medium density fiberboard	Thousand Square feet 3/4 inch	62.50	45.0	0.92	0.647
Hardboard	Thousand Square feet 1/8 inch	10.42	60	0.97	0.152
Insulation board	Thousand Square feet 1/2 inch	41.67	23.5	0.99	0.184
6. Other industrial products	Thousand cubic feet	1.00	33.0	1.00	8.250

Table A2 -- Fraction of solidwood product production used in various end uses in the U.S. and used for export, 1998

End use	Product				
	Lumber[a]		Structural panels[b]		Non-structural panels[c]
	Softwood	Hardwood	Softwood plywood	OSB	
New residential construction					
Single family	0.332	0.039	0.334	0.578	0.130
Multifamily	0.031	0.004	0.033	0.047	0.019
Mobile homes	0.039	0.002	0.035	0.060	0.037
Residential upkeep & improvement[d]	.253	0.039	0.243	0.164	0.112
New nonresidential construction					
All except railroads	0.079	0.028	0.090	0.071	0.053
Railroad ties	0.001	0.047	0.000	0.000	0.000
Railcar repair	0.000	0.008	0.001	0.000	0.000
Manufacturing					
Household furniture	0.023	0.235	0.046	0.002	0.138
Commercial furniture	0.004	0.048	0.050	0.006	0.218
Other products	0.035	0.095	0.083	0.021	0.094
Shipping					
Wooden containers	0.006	0.008	0.008	0.000	0.005
Pallets	0.037	0.349	0.025	0.001	0.001
Dunnage etc	0.002	0.007	0.000	0.000	0.000
Other uses	0.126	0.007	0.009	0.041	0.139
Total domestic use	0.967	0.917	0.957	0.991	0.946
Export	0.033	0.083	0.043	0.009	0.054

[a]Includes hardwood and softwood dimension and boards, glulam, and lumber I-joist flanges.
[b]Includes softwood plywood, OSB, structural composite lumber, and I-joist webs.
[c]Includes hardwood plywood, particleboard, medium-density fiberboard, hardboard, and insulation board.

Other uses for lumber and panels includes 1) upkeep and improvement of nonresidential structures, 2) roof supports and other construction in mines, 3) made-at-home projects such as furniture, boats, and picnic tables, 4) made-on-the-job products such as advertising and display structures, 5) other uses not included elsewhere

Source: McKeever, D.B. 2002.

Table A3 – Half life for products in end uses

End use or product	Half life in years
New residential construction	
Single family	100
Multifamily	70
Mobile homes	12
Residential upkeep & improvement	30
New nonresidential construction	
All ex. railroads	67
Railroad ties	12
Railcar repair	12
Manufacturing	
Household furniture	30
Commercial furniture	30
Other products	12
Shipping	
Wooden containers	6
Pallets	6
Dunnage etc	6
Other uses for lumber and panels	12
Solid wood exports	12
Paper	2

Sources: Skog and Nicholson, 1998; Row and Phelps, 1996

Table A4 - Fraction of discarded wood and paper placed in landfills		
Year	**Wood to landfills**	**Paper to landfills**
1950	5%	5%
1951	6%	5%
1952	6%	6%
1953	7%	6%
1954	7%	6%
1955	8%	6%
1956	8%	7%
1957	9%	7%
1958	9%	7%
1959	10%	7%
1960	11%	9%
1961	12%	9%
1962	13%	10%
1963	13%	10%
1964	14%	11%
1965	15%	11%
1966	17%	13%
1967	19%	15%
1968	22%	17%
1969	24%	19%
1970	26%	21%
1971	29%	23%
1972	32%	25%
1973	35%	27%
1974	37%	29%
1975	40%	32%
1976	43%	34%
1977	49%	38%
1978	55%	43%
1979	62%	48%
1980	68%	52%
1981	69%	53%
1982	71%	53%
1983	72%	53%
1984	73%	54%
1985	74%	54%
1986	76%	54%
1987	77%	54%
1988	78%	54%
1989	79%	54%
1990	74%	54%
1991	79%	50%
1992	71%	48%

1993	70%	48%
1994	70%	44%
1995	73%	39%
1996	71%	37%
1997	69%	38%
1998	68%	39%
1999	68%	39%
2000	67%	37%
2001	67%	35%
2002	67%	34%
Sources: US EPA, 2003, ICF Consulting, 2004; USDA Forest Service, Forest Product Laboratory		

Table A5 - Non degradeable fraction of wood and paper in landfills and half life for degradable fraction

Non degradable fraction in landfills:	
wood	0.77
paper	0.44
Half life of degradable fraction in years	14

Source: Barlaz, 1998 and ICF Consulting, 2003 for non degradable fraction; IPCC, 2001, p 5.7 for decay half life.

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